LAGUNA-LBNO:
Design of a pan-European Infrastructure for Large Apparatus studying Grand Unification, Neutrino Astrophysics and Long Baseline Neutrino Oscillations

Deep Underground Science Facilities for ν Physics & Proton decay
Prospects for a next generation ν observatory on 100’000m^3 scale
Progress in Europe

André Rubbia (ETH Zurich)
on behalf of LAGUNA Consortium

http://www.laguna-science.eu/

LBNE Collaboration meeting, UCLA
January 2011, Los Angeles, USA

LAGUNA-LBNO

Switzerland
University Bern
University Geneva
ETH Zürich
Lombardi Engineering

Finland
University Jyväskylä
University Helsinki
University Oulu
Rockplan Oy Ltd

CERN

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Technodyne Ltd
Alan Auld Ltd
Ryhal Engineering

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Bucharest

Denmark
Aahrus

Italy
AGT

Russia
INR
PNPI

Japan
KEK

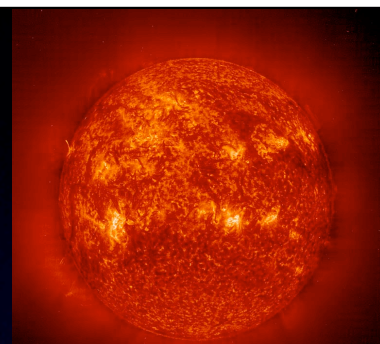
Science of LAGUNA-LBNO

See Ref. D. Autiero et al., JCAP 0711 (2007) 011

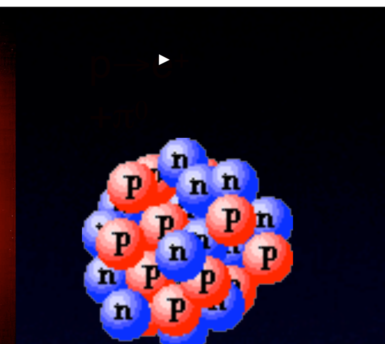
Physics "white paper" in preparation (Editor: S. Pascoli)

Particle Physics and Particle Astrophysics

Supernova neutrinos



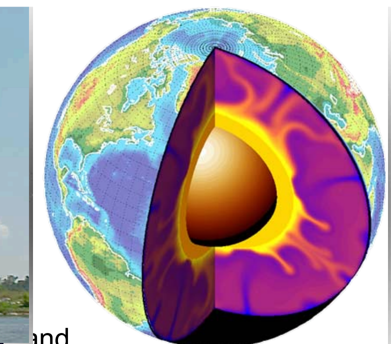
Solar neutrinos



Proton decay

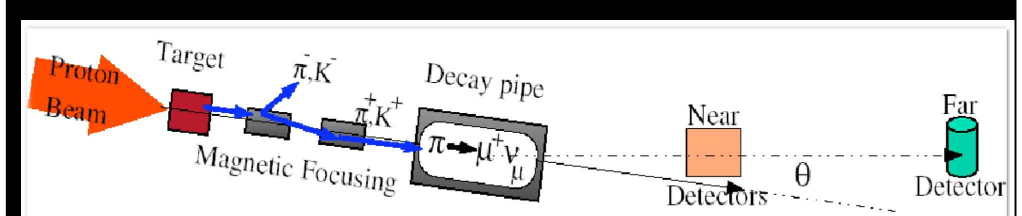
Atmospheric neutrinos

Reactor neutrinos

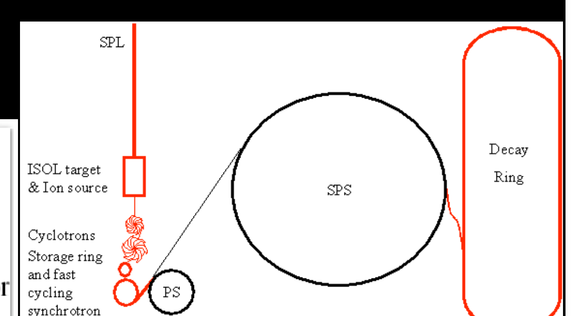


Geo neutrinos

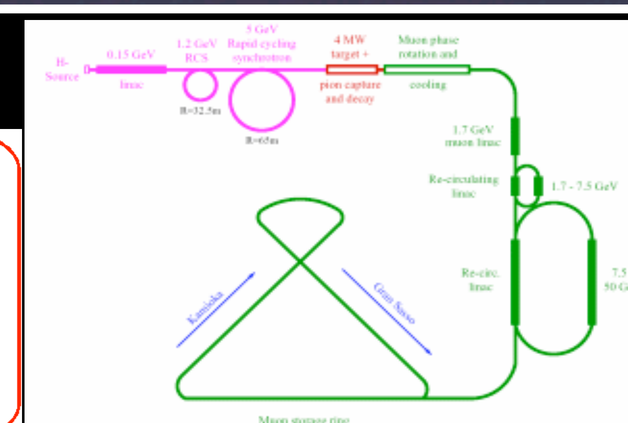
Long baseline neutrinos with accelerators



Superbeams



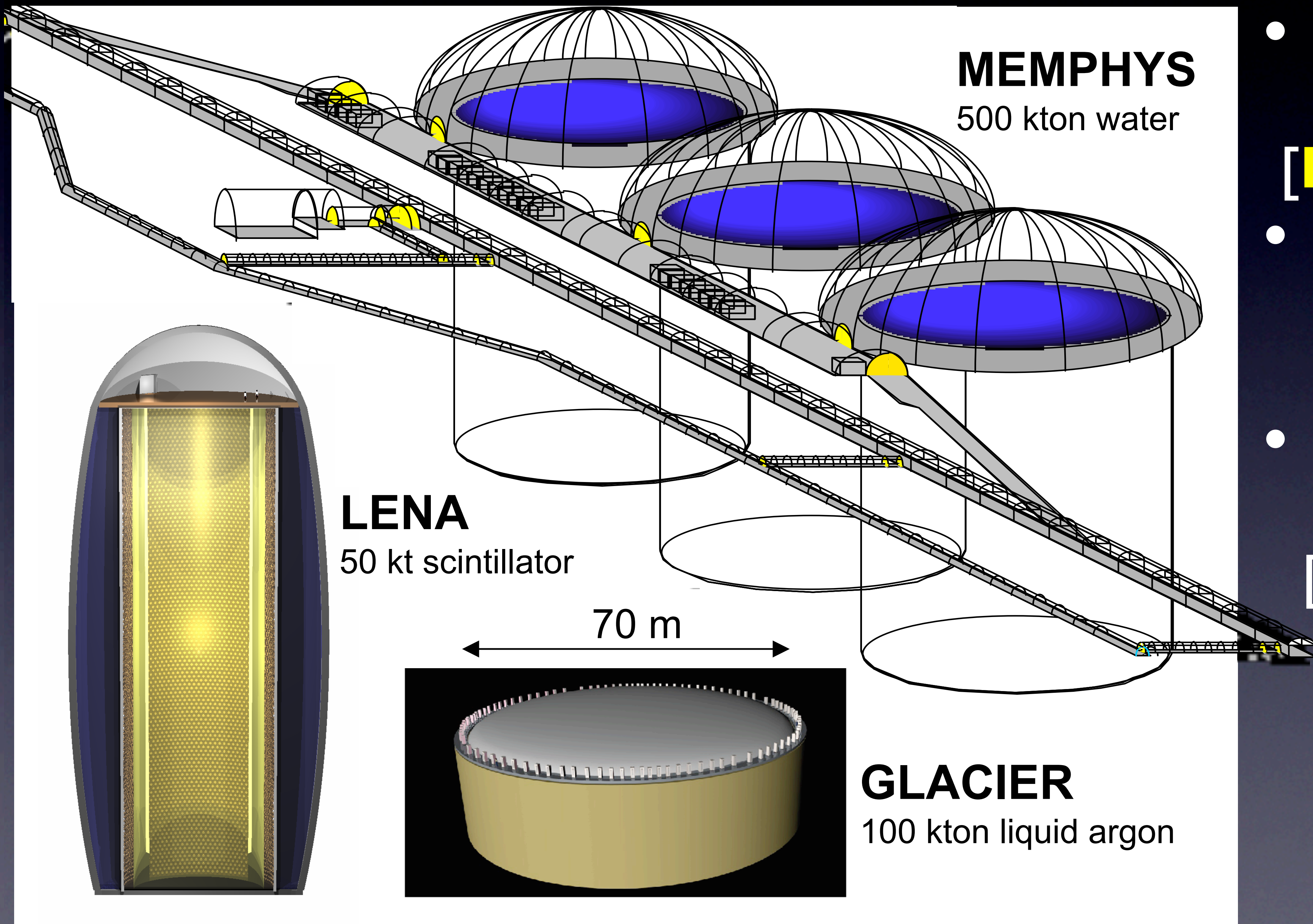
Betabeams



Neutrino factory

Detector technology options

- **Next generation deep underground neutrino observatory**
  - Three technology options considered (MEMPHYS, LENA, GLACIER) with total active mass in the range 50'000-500'000 tons



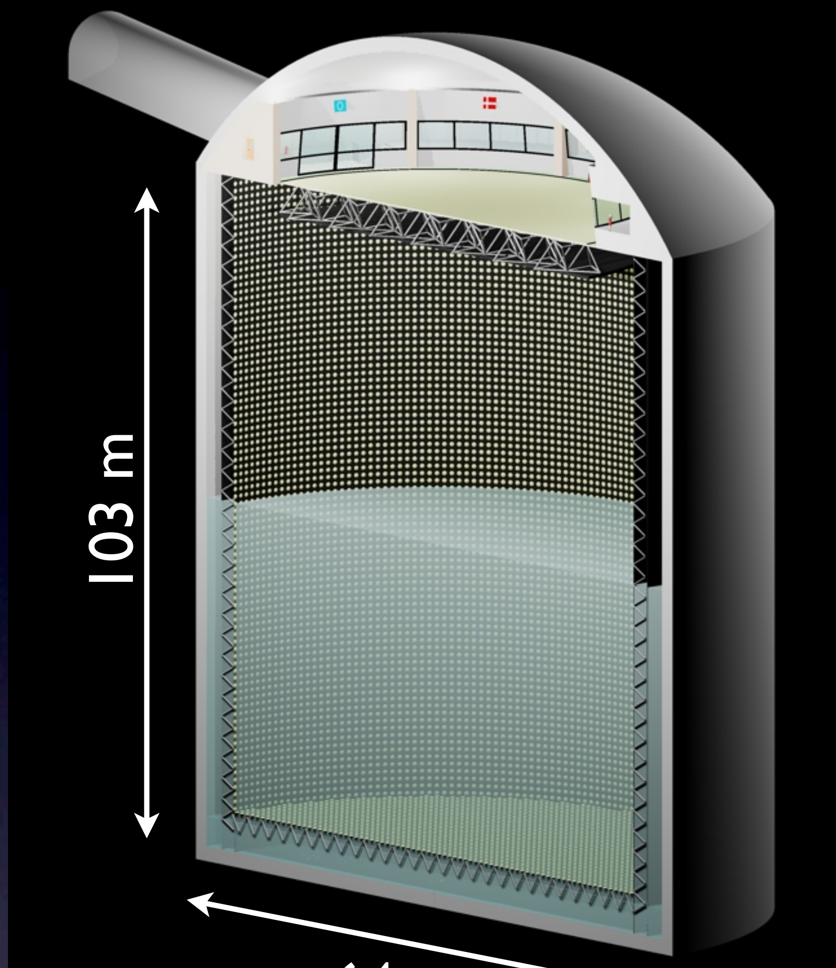
- Water Cerenkov [**MEMPHYS**]
- Liquid scintillator [**LENA**]
- Liquid Argon TPC [**GLACIER**]

Outstanding astroparticle ν physics and proton decay search

	Water Cerenkov	Liquid Argon TPC	Liquid Scintillator
Total mass	500 kton	100 kton	50 kton
$p \to e\,\pi^0$ in 10 years	1.2×10^{35} years ε = 17%, ≈ 1 BG event	0.5×10^{35} years ε = 45%, <1 BG event	?
$p \to \nu\,K$ in 10 years	0.15×10^{35} years ε = 8.6%, ≈ 30 BG events	1.1×10^{35} years ε = 97%, <1 BG event	0.4×10^{35} years ε = 65%, <1 BG event
SN cool off $8\times M_{Sun}$@ 10 kpc	194000 (mostly $\bar{\nu}_e p \to e^+ n$)	38500 (all flavors) (64000 if NH-L mixing)	15000 (all flavors)
SN in Andromeda	40 events	7 (12 if NH-L mixing)	4 events
SN burst @ 10 kpc	≈250 ν-e elastic scattering	380 ν_e CC (flavor sensitive)	≈30 events
SN relic	250(2500 when Gd-loaded)/year	50/year	20-40/year
Atmospheric neutrinos	56000 events/year	≈11000 events/year ≈100 ντ CC/year	5600/year
Solar neutrinos	91250000/year	324000 events/year	≈5400 ^{7}Be events/day
Geoneutrinos	–	–	≈1500 events/year

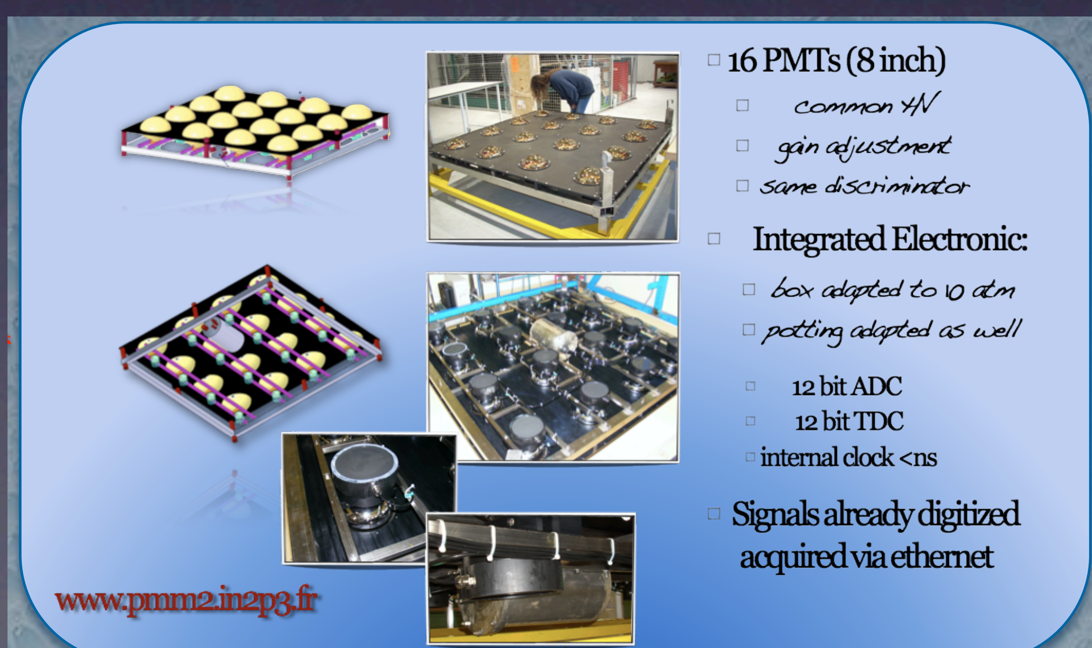
Complementarity between detector techniques

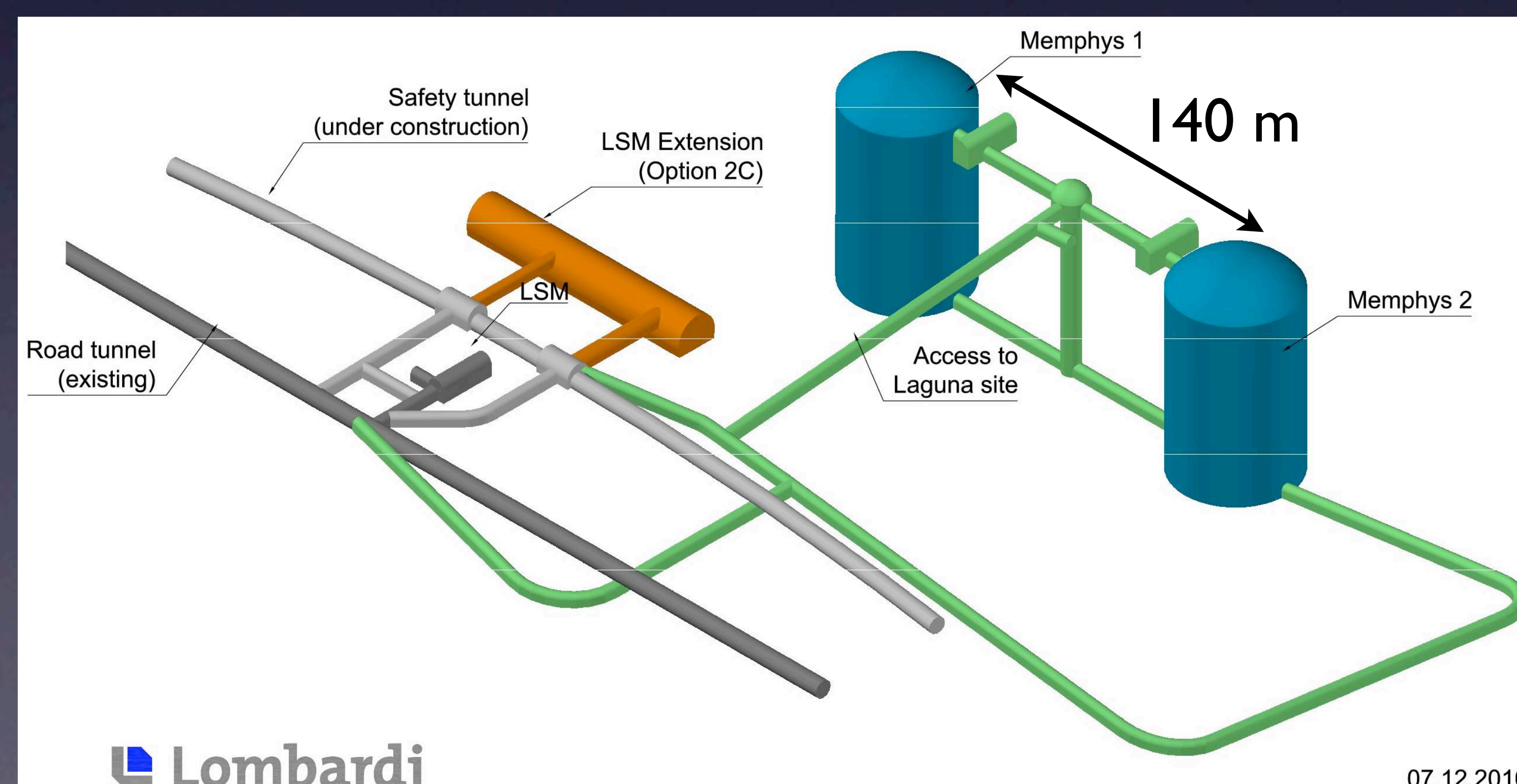
MEMPHYS option (Large Water Cerenkov)



Extrapolation from SuperKamiokande

2 independent modules,
330’000 m^3 each
220’000 8-10” PMTs
≈500 kton fiducial mass





LENA option
(Low Energy Neutrino Astronomy)

Very high purity liquid scintillator with high light yield, optimized for lowest energy range

Liquid scintillator
50 kt LAB/PPO+ bisMSB
Inner vessel (nylon)
Radius r = 13m
Buffer
15kt LAB, Δr =2m
Cylindrical steel tank, e.g. 55000 PMTs (8") with Winston Cones (2x area)
r = 15m, height = 100m,
optical coverage: 30%
Water cherenkov muon veto
5,000 PMTs, Δr > 2m to shield fast neutrons
Cavern egg-shaped for increased stability
Rock overburden: 4000 mwe

Pyhäsalmi design

Desired **energy resolution**
→ 30% optical coverage
→ 3000m² effective photo-sensitive area

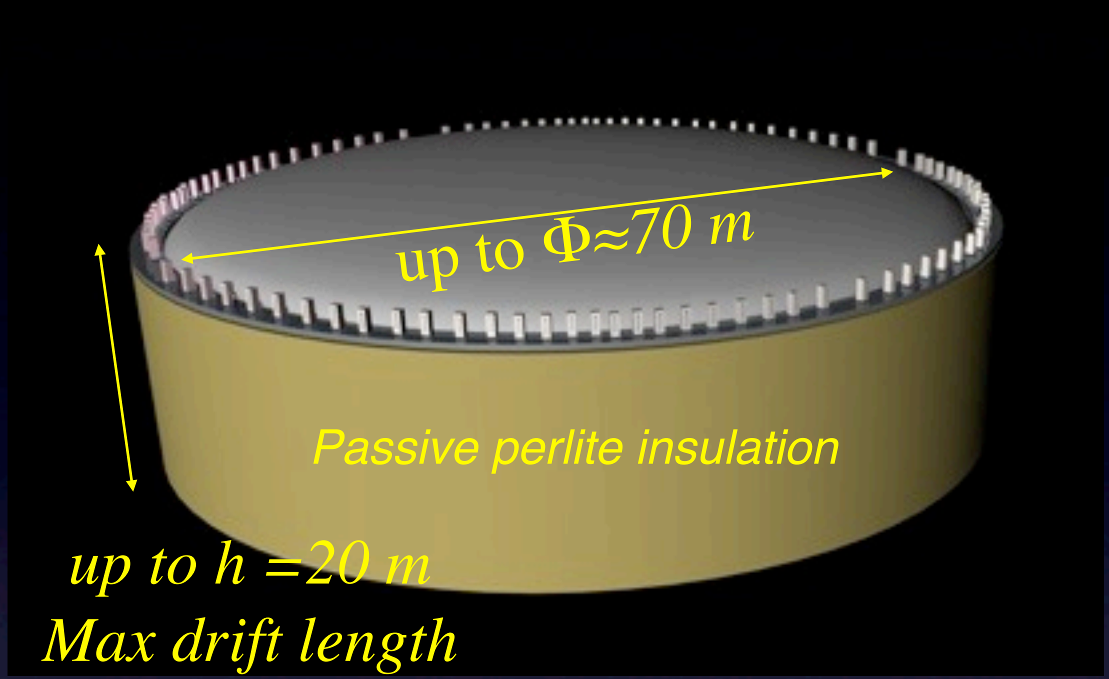
Light yield ≥ 200 pe/MeV

The **tracking option** adds to the requirements of the PMT array and electronics:
→ more, but smaller, faster PMTs
→ full waveform digitizing

LS purity as achieved in Borexino

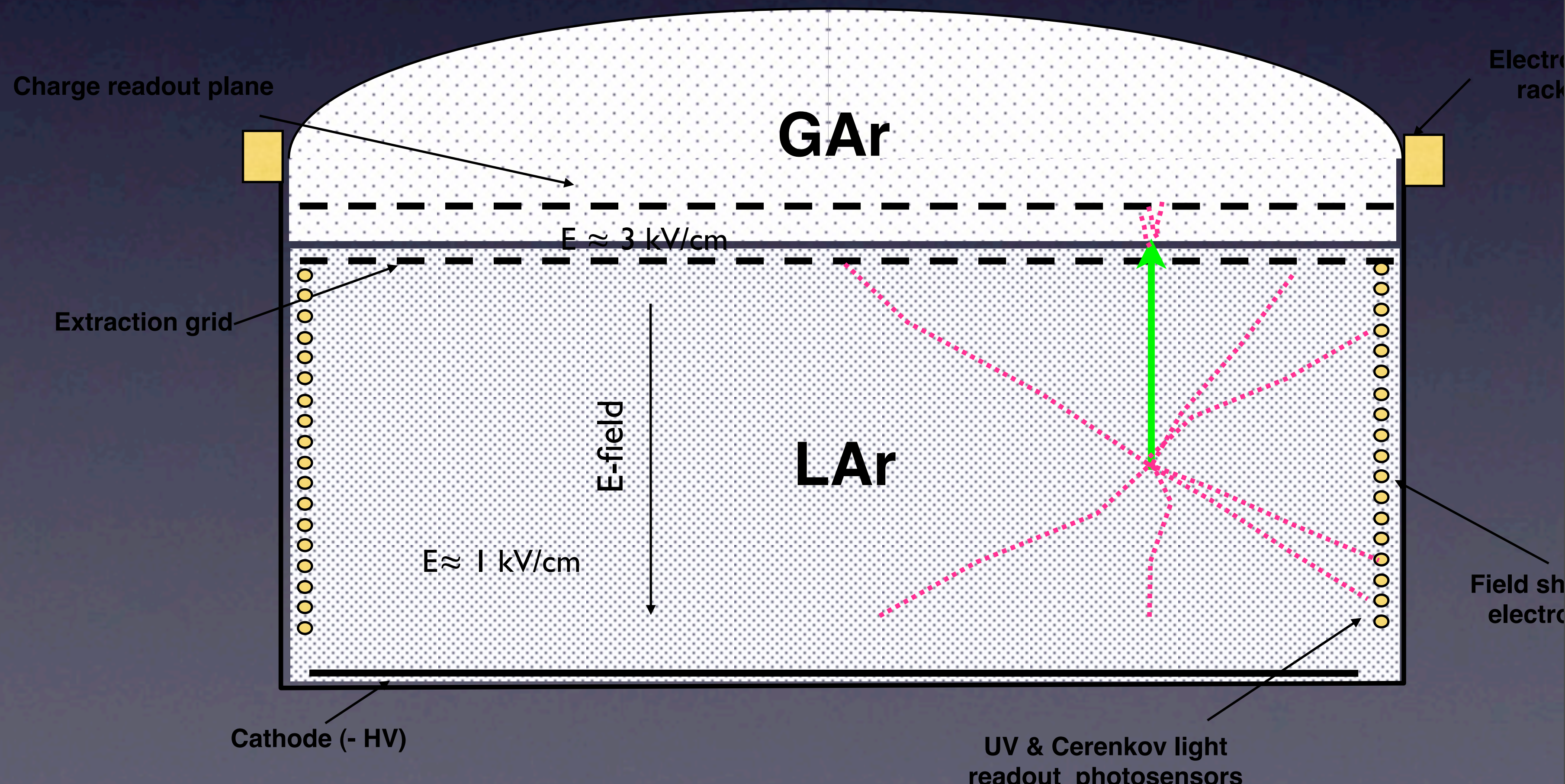
GLACIER option

(Giant Liquid Ar Charge Imaging ExpeRiment)



- Single module non-evacuable cryo-tank based on industrial LNG technology
- Cylindrical shape with excellent surface / volume ratio
- Simple, scalable detector design, possibly up to 100 kton
- Single very long vertical drift with full active mass
- A very large area LAr LEM-TPC for long drift paths
- Possibly immersed visible light readout for Cerenkov imaging
- Possibly immersed (high Tc) superconducting solenoid to obtain magnetized detector
- Reasonable excavation requirements (<250‘000 m^3)

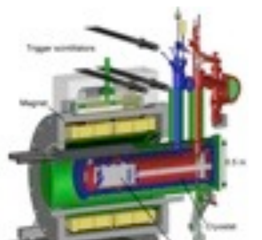
Double phase liquid Argon TPC with charge amplification.



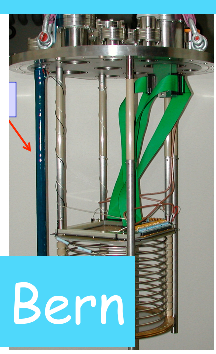
GLACIER R&D: steps

Single phase LArTPC

KEK

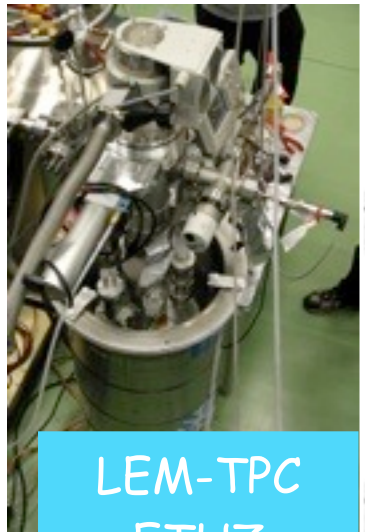


B-field test

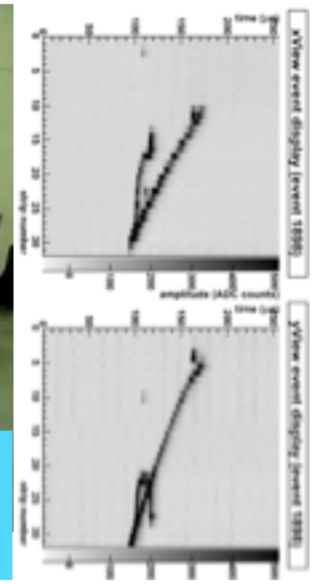


Bern

Double phase LAr-LEM TPC



LEM-TPC ETHZ



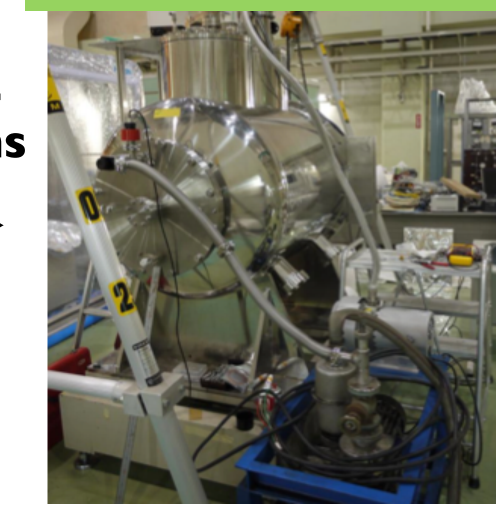
ArDM-1t(RE18), presently operating@CERN

Move to LSC in 2011

Test beams

P32@JPARC

Beam exposed in 2010 (and 2011?)



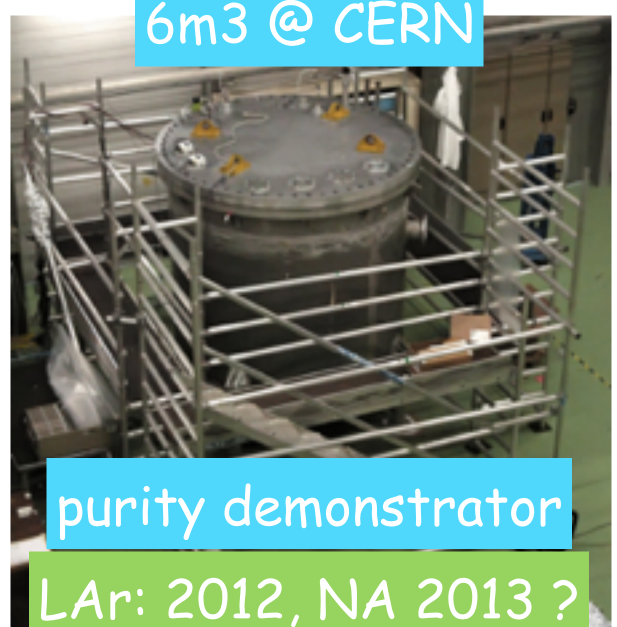
direct proof of long drift path up to 5 m

ArgonTube @Bern

run in 2011

Test beams

6m3 @ CERN



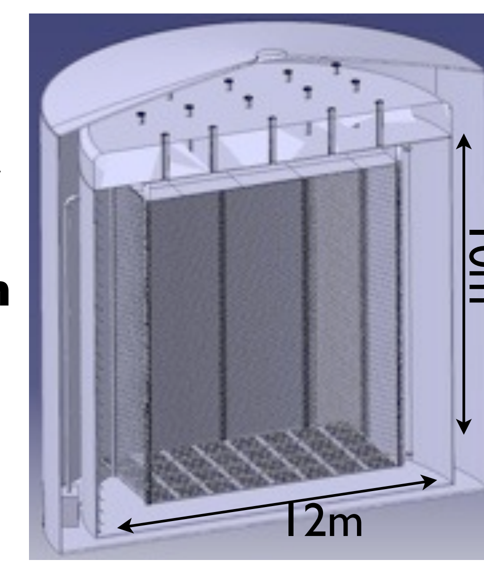
purity demonstrator

LAr: 2012, NA 2013 ?

Charged particles test beam, calorimetry, non-evacuated vessels, LAr purity

Full engineering demonstrator for larger detectors, with a stand-alone short baseline physics programme

1 kton ?

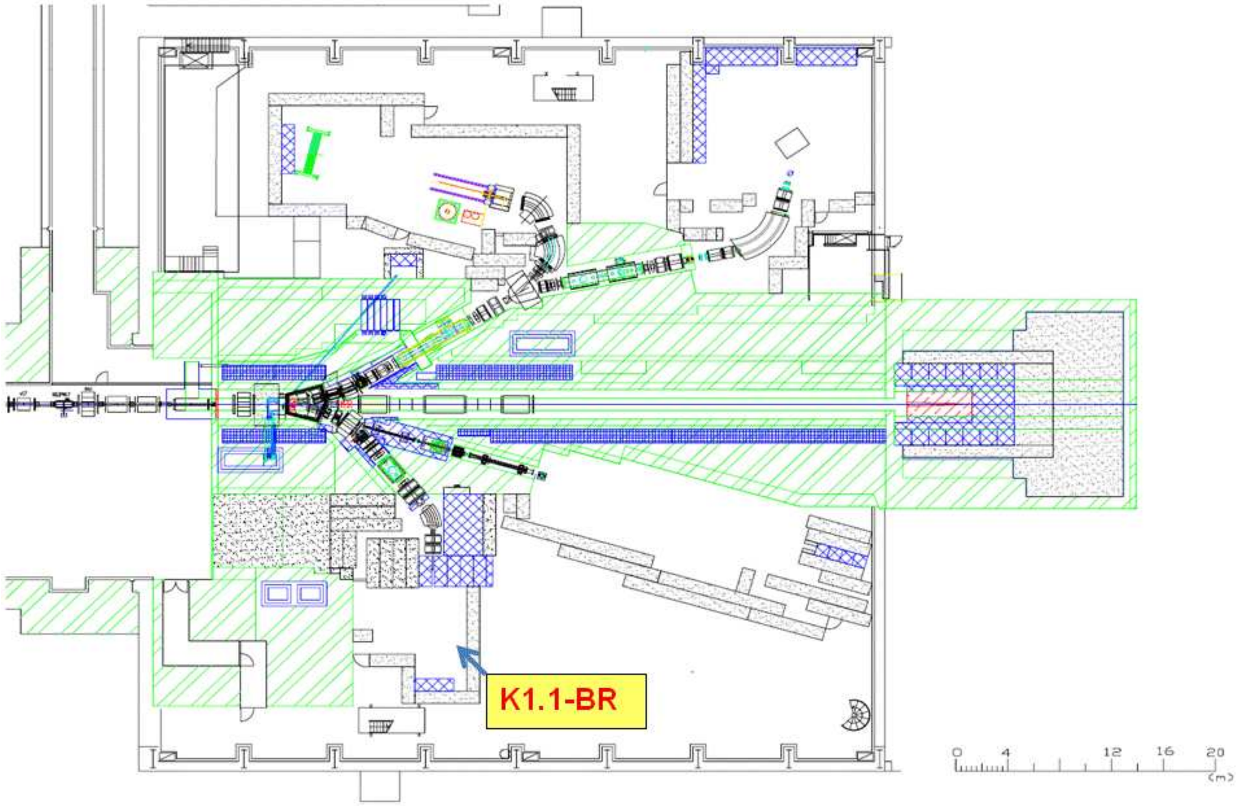


NEW: J-PARC P32 test beam

ETHZ-KEK-Iwate-Waseda

Measurements with well defined charged particle test beam at J-PARC slow extraction:

- **To benchmark performance of detector**
- **To develop simulation/reconstruction software**
- **Kaon id relevant for proton decay searches**



Trigger tagging from beamline instrumentation (TREK)
Fitch Cerenkov, TOF, gas Cerenkov

T32: Accumulated No. of Events 24-Oct − 1-Nov

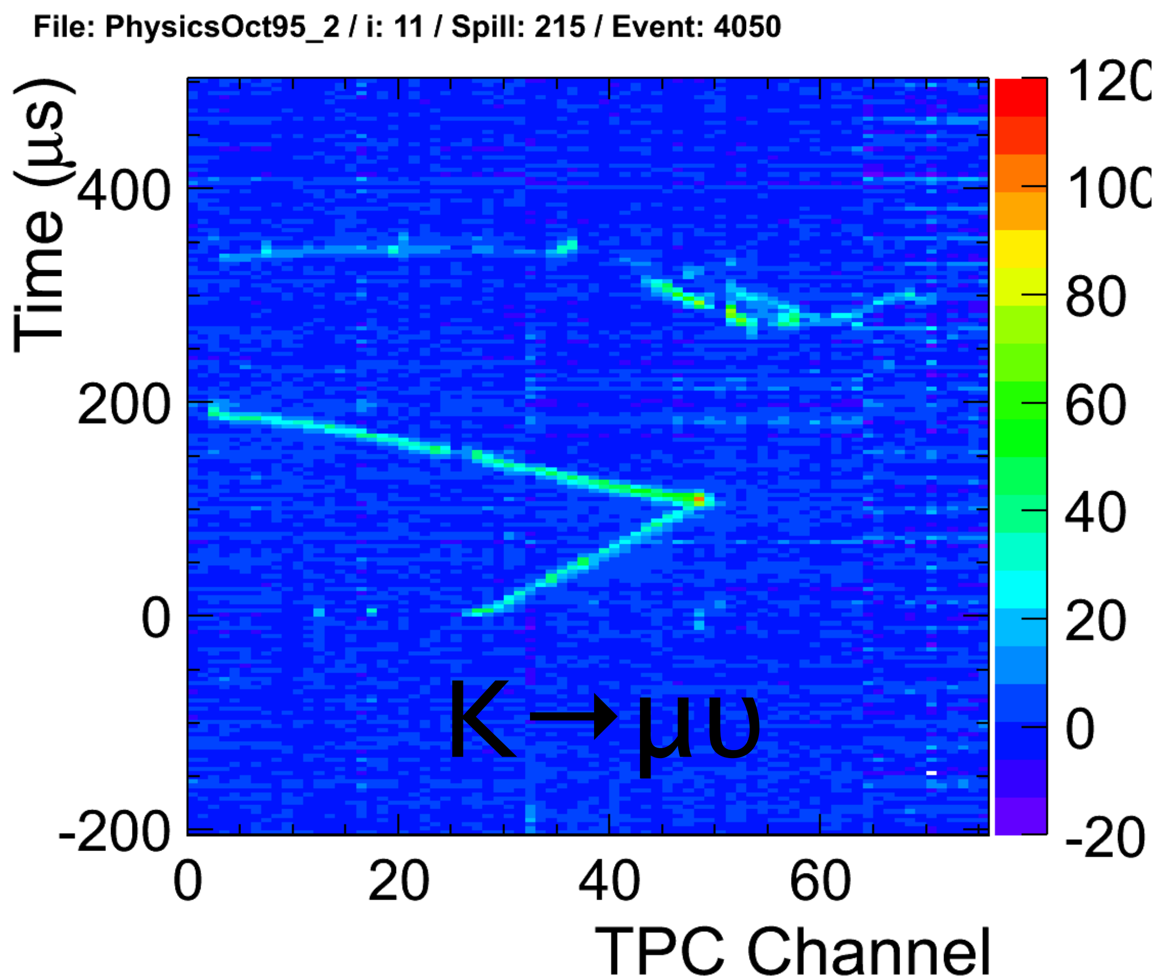
Event Category	No. of events
K^+ 800 MeV/c with degrader → 540 MeV/c	7,000
K^+ 800 MeV/c with degrader → 630 MeV/c	40,000
K^+ 800 MeV/c with degrader → 680 MeV/c	35,000
π^+ 200 MeV/c	70,000
e^+ 800 MeV/c	2,500
P 800 MeV/c	1,500
e^+ 200 MeV/c	10,000
π^+ dominant 800 MeV/c	～ 3,000
total	～170,000

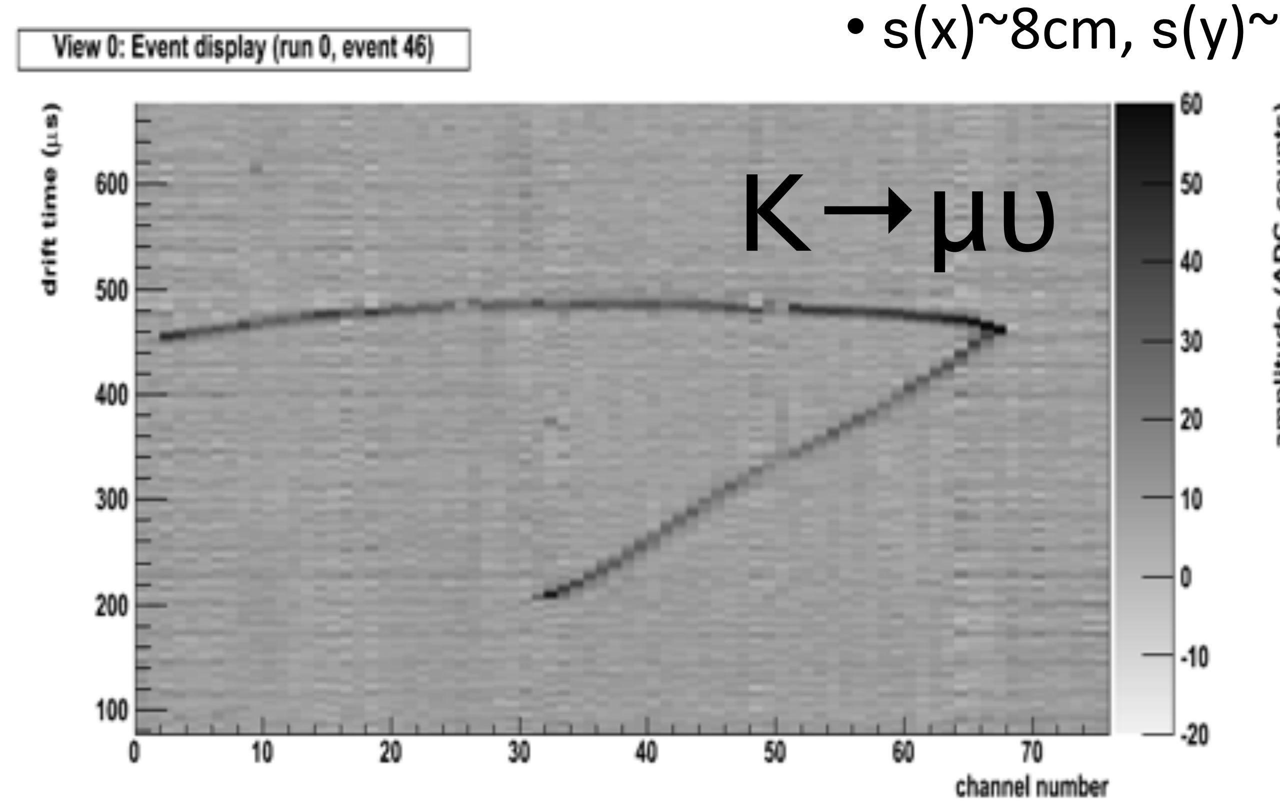
J-PARC P32 event gallery

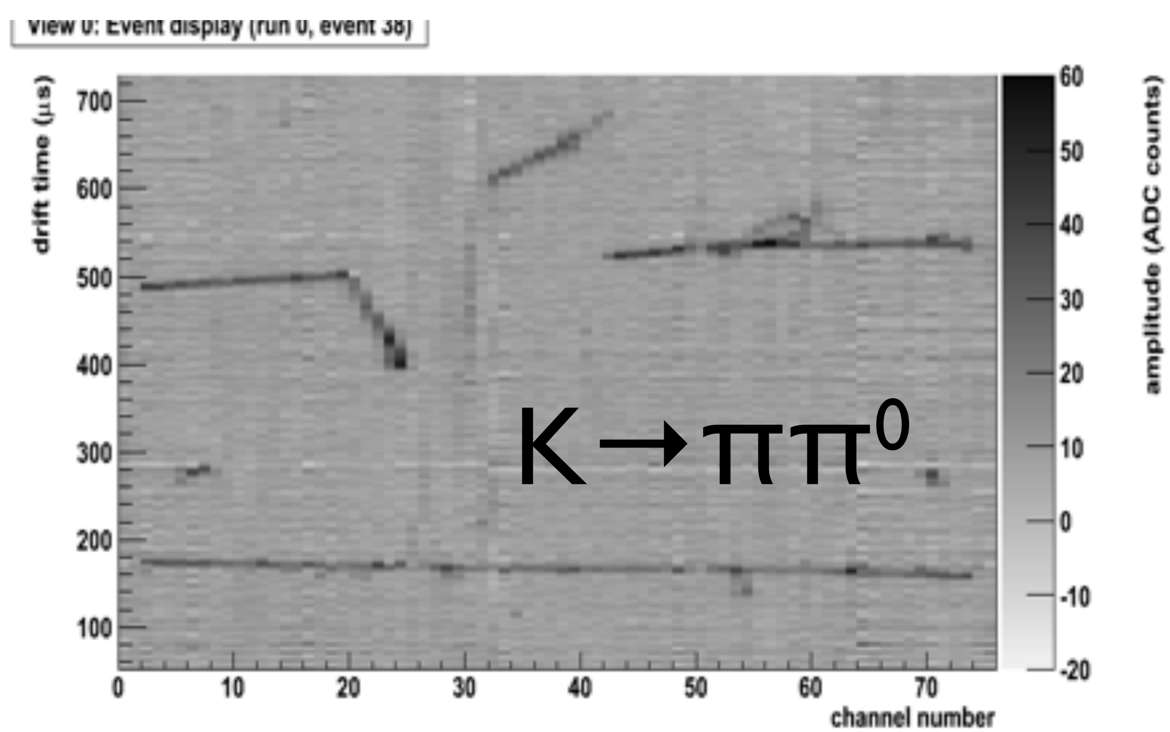
Tagged separated kaon beam at K1.1BR beam area @ hadron hall

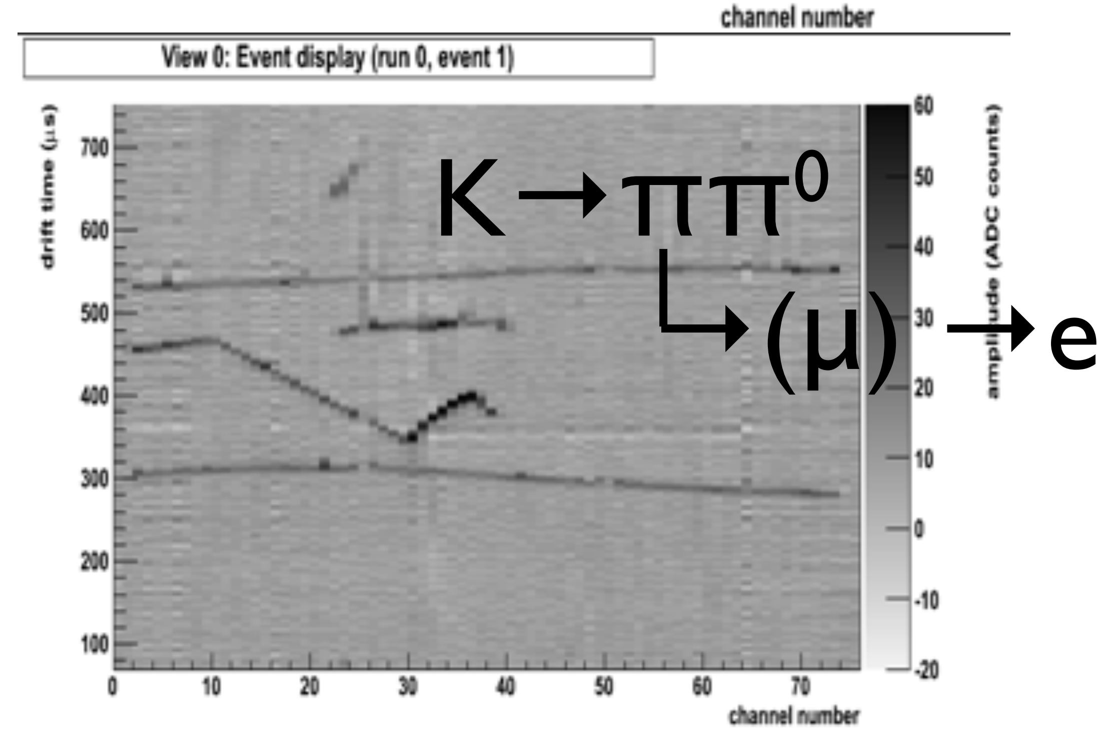
- 0.8 GeV/c K/π ratio ≈ 1/4
- a few K/flat top(=2s)

- beam profile (@degrader)
  - s(x)~8cm, s(y)~6cm









LAGUNA at work (2008-2011)

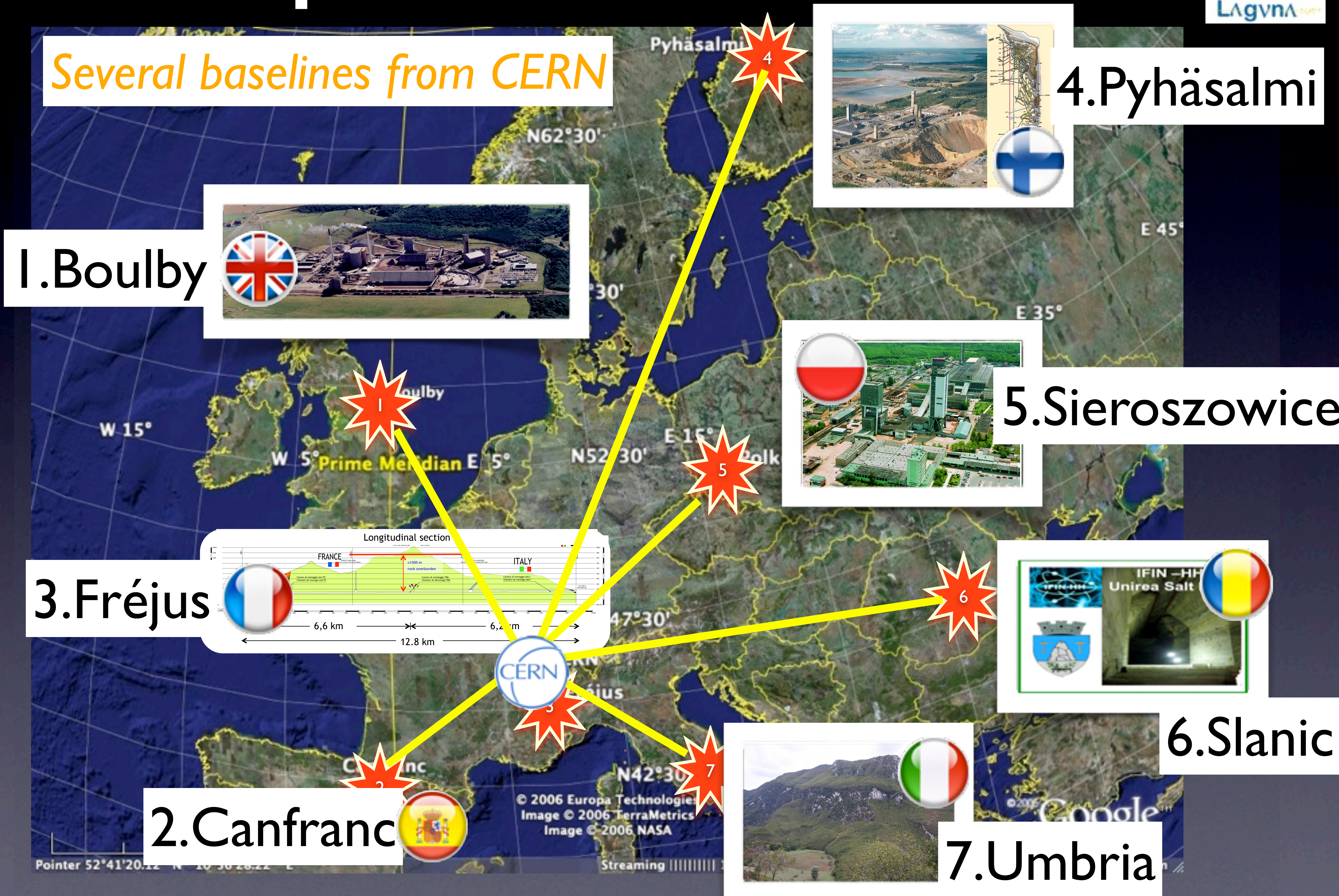
Typical questions addressed

- assessment of strengths and weaknesses
- rock mechanics of caverns
- design of tanks in relation to sites
- overburden vs. detector options
- transport, access, delivery of liquids
- safety e.g. tunnel vs. mine
- environment e.g. rock removal
- relative costs

Site visits and meeting

- sites work together on common areas

Seven pre-selected EU sites



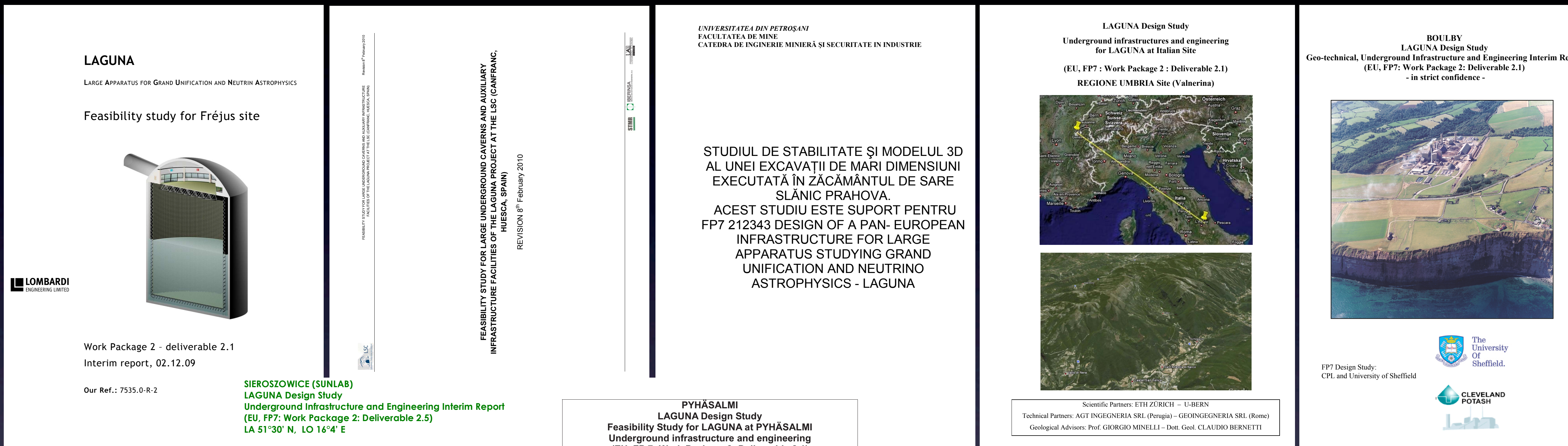
Site features

Basic characteristics of the studied underground sites:

From existing road tunnels:	Canfranc (1500-2700mwe), Fréjus (4800mwe)
From existing deep mines:	Boulby (3400-4000mwe), Pyhäsalmi (2500-4000mwe), Sieroszowice (1400mwe)
Existing large salt-mine:	Slanic (840mwe)
Greenfield site(off-axis CNGS):	Umbria (1500-2300mwe)

Seven technical reports

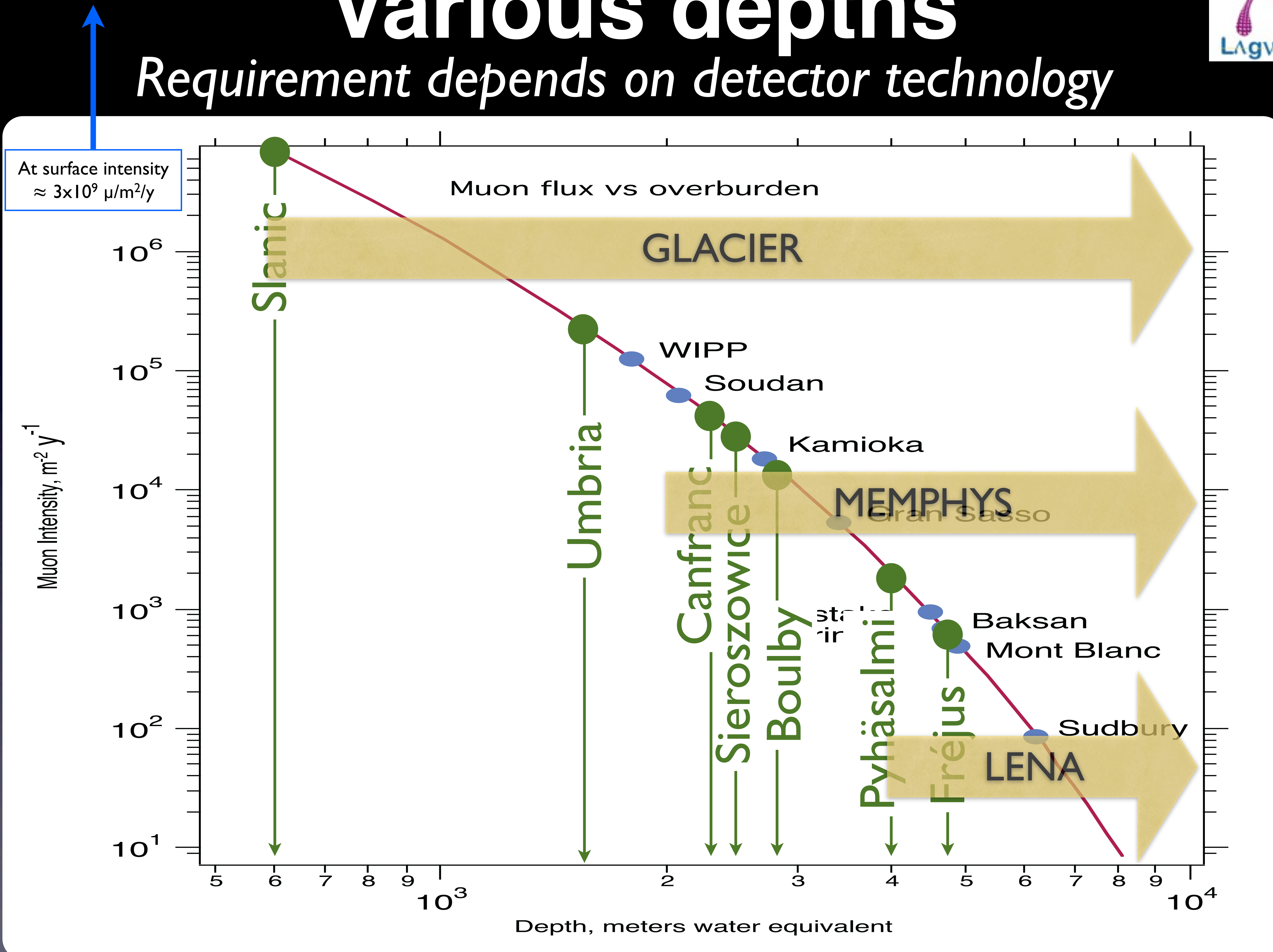
Interim site-dependent geotechnical reports: delivered!
Final joint report on potential European sites: soon



- more than 1200 pages
- large amount of information and details
- healthy competition among sites
- publicly available

Various depths

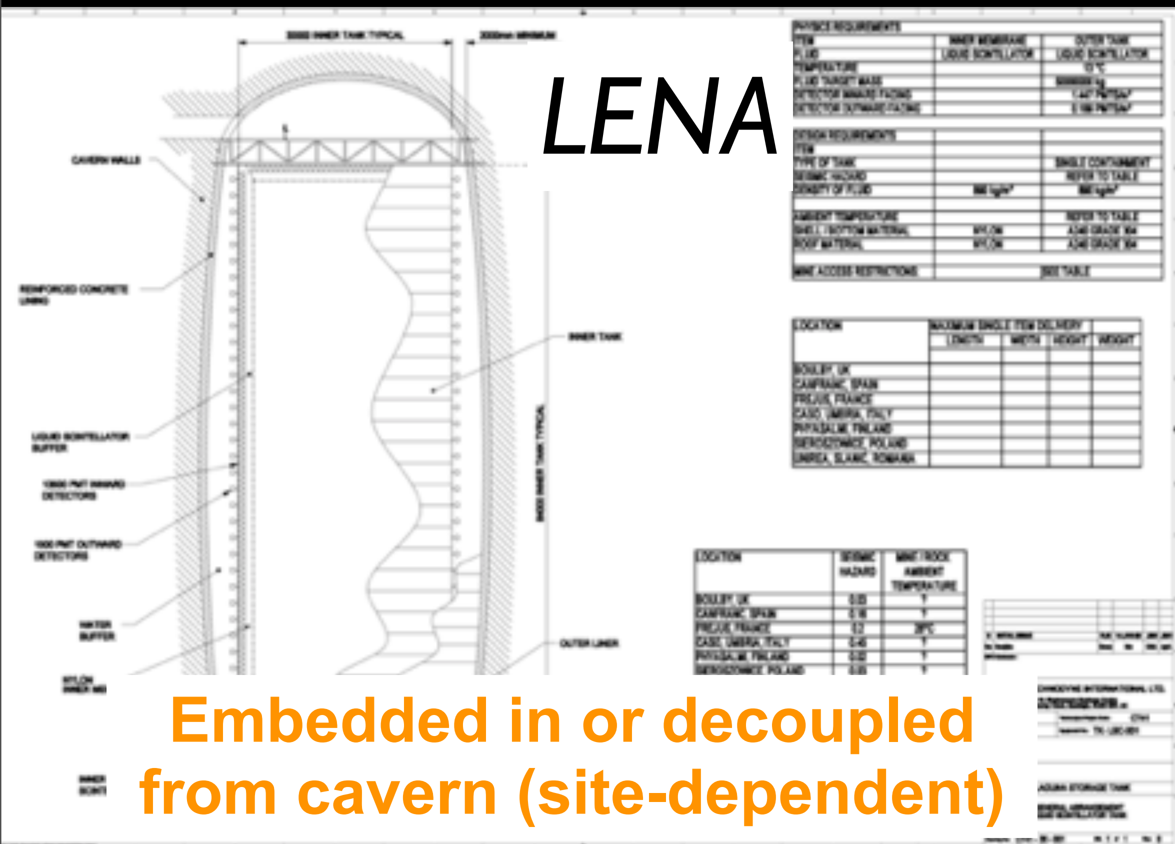
Requirement depends on detector technology



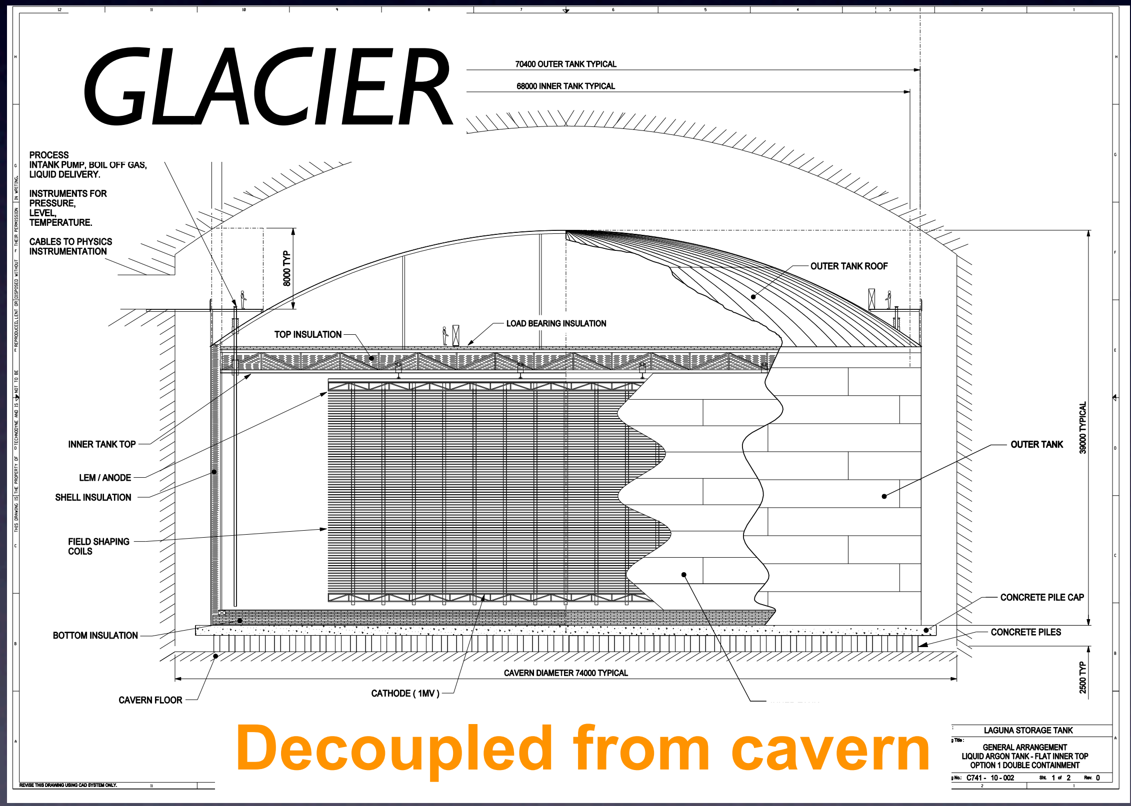
(1) Tank concepts

80 pages report by Technodyne Ltd

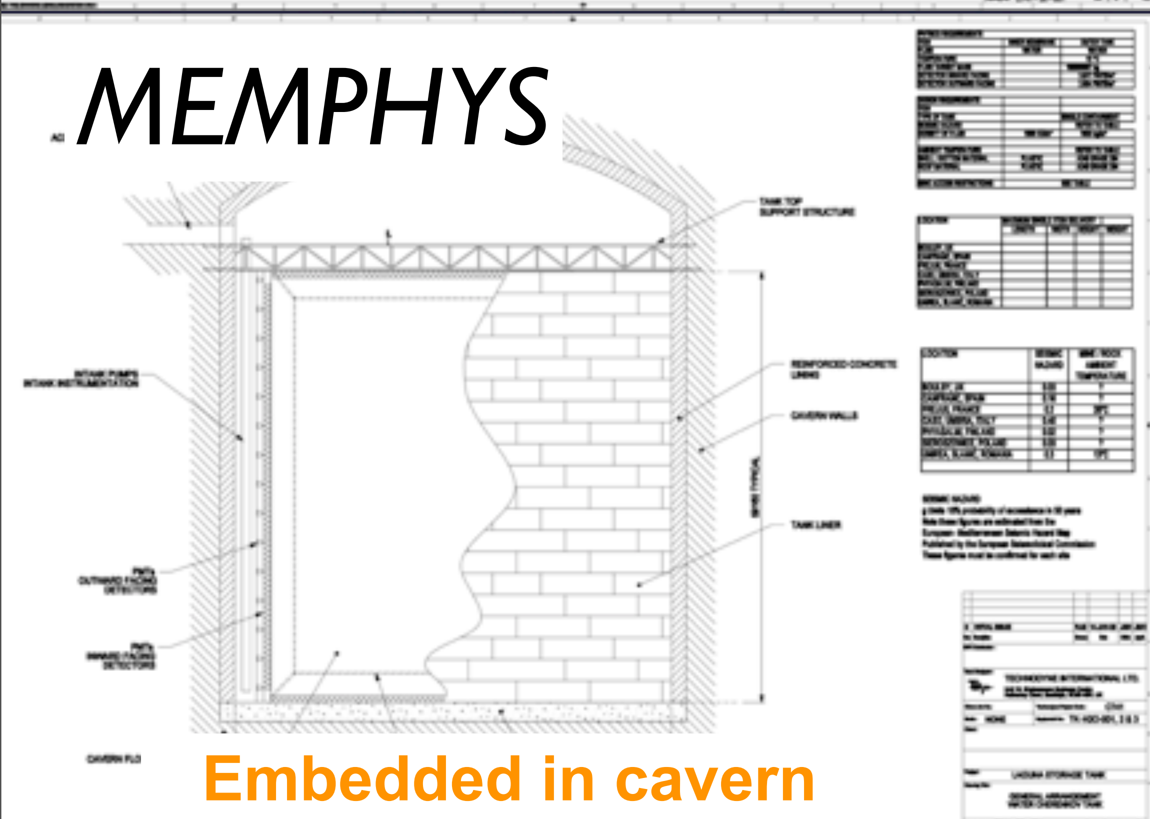
Item	MEMPHYS	Lena	Glacier
Type	Single Containment	Single Containment	Single or Double Containment
Inner Membrane	Plastic	Nylon	-
Liquid Holding Tank	Stainless Steel	Stainless Steel	Stainless Steel
Cavern Liner	Stainless Steel	Stainless Steel	9% Nickle Steel or Carbon Steel



Embedded in or decoupled from cavern (site-dependent)



Decoupled from cavern



Embedded in cavern

Preliminary tank cost estimates have been established as follows:

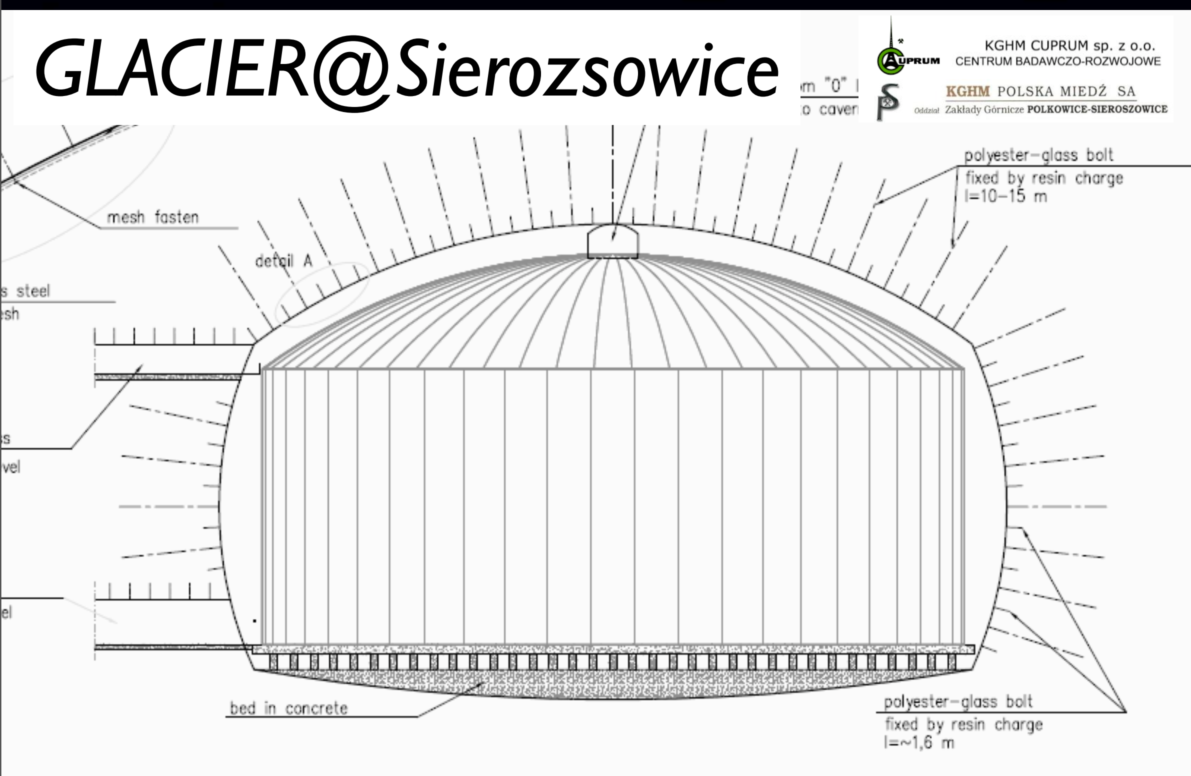
GLACIER tank (Low Seismic Site)	M€
GLACIER tank (High Seismic Site)	M€
LENA tank	M€
MEMPHYS tanks (total for 3 off)	M€

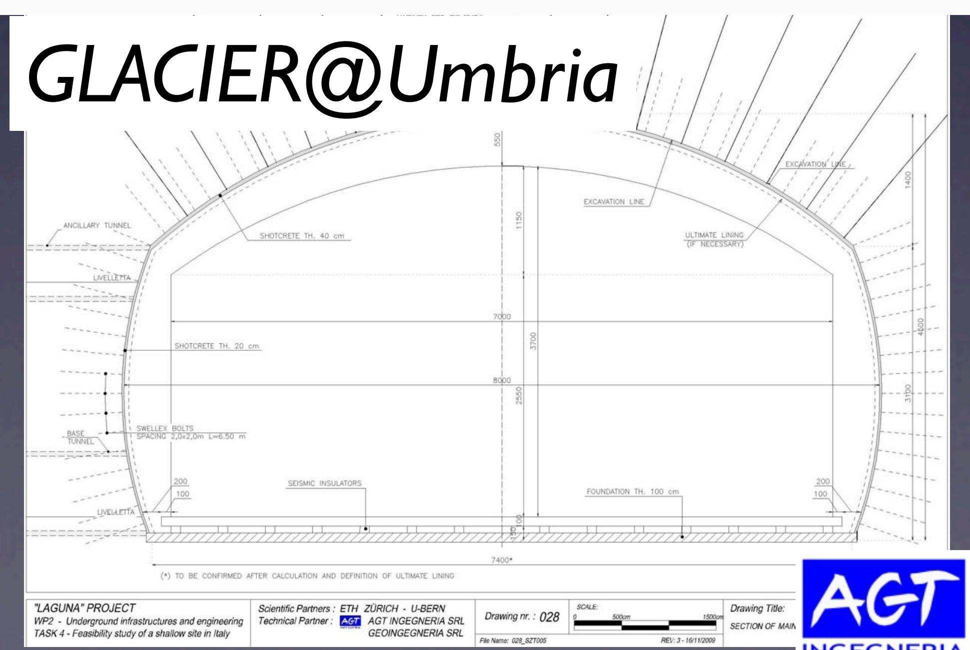
(2) Main cavern engineering

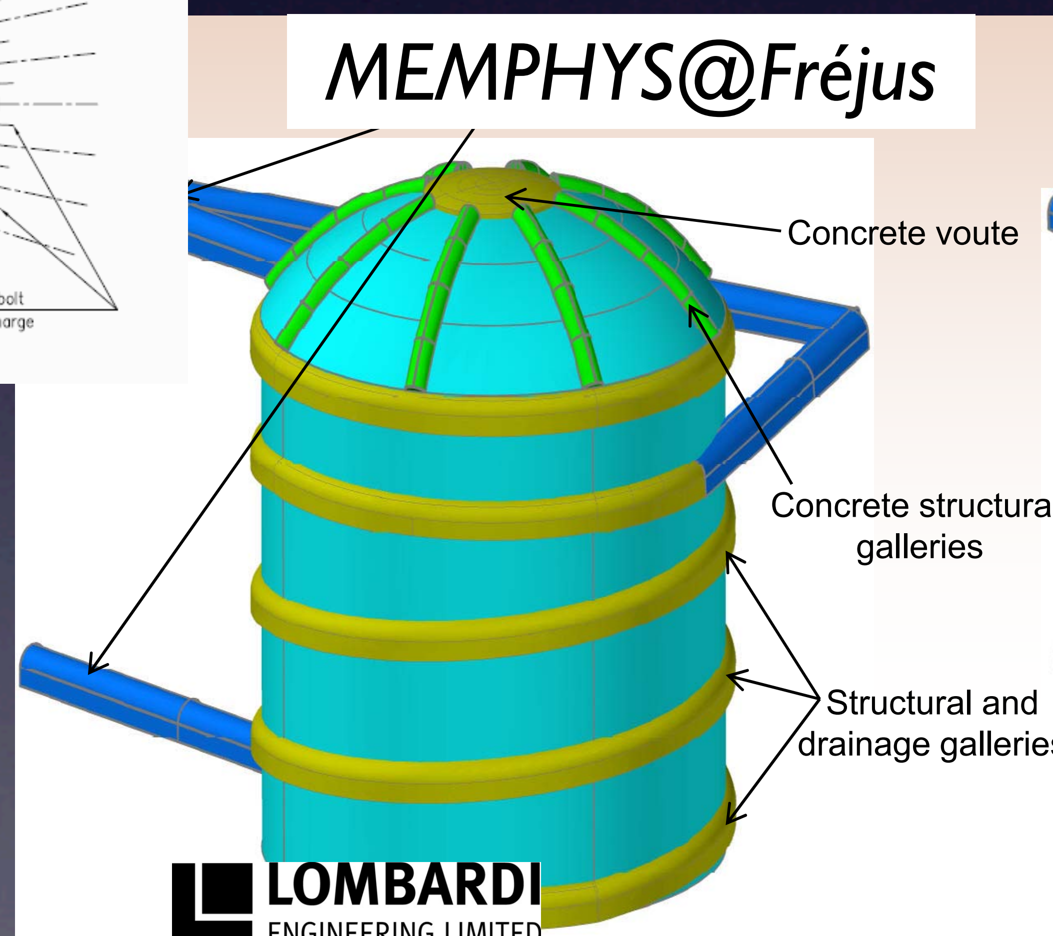
Relationship between tank design and main cavern excavation

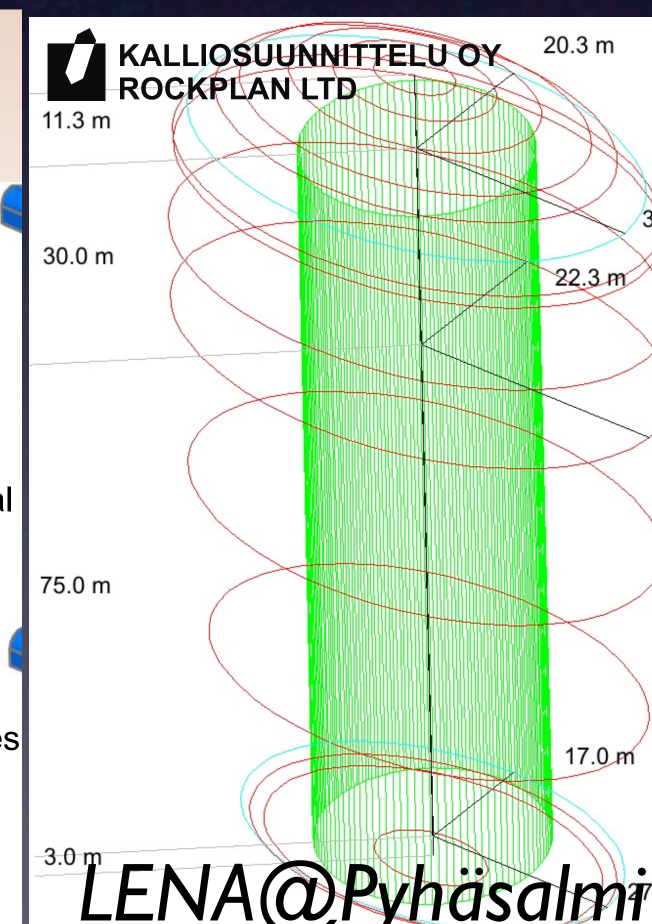
- **Interaction between scientists, Technodyne Ltd. with Rockplan, Cuprum, CPL, AGT, ...**

	MEMPHYS	LENA	GLACIER
Overburden	>2000 mwe	>4000 mwe	>600 mwe
#tanks	3 to 5	1	1 preferred
Dimensions of tank	cylinder 65m Ø x 65m height	SS cylinder of 30m Ø x105 m height, inside a external tank of ~ cylindrical shape, of at least 34m Ø for water-buffer.	cylinder: 72,4m Ø x 26,5m height dome: 12,7m height x 144,8m Ø
Cavern	65m Ø x 70m height + dome	Egg-shaped to house external tank	cylinder: 75,1m Ø x 26,5m height + dome





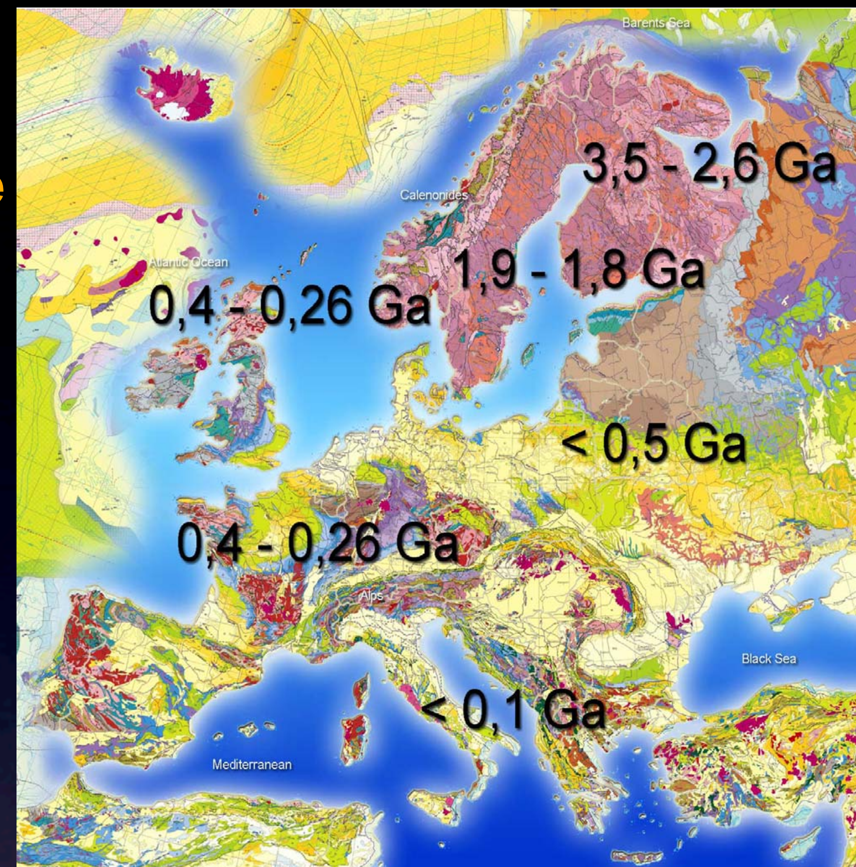


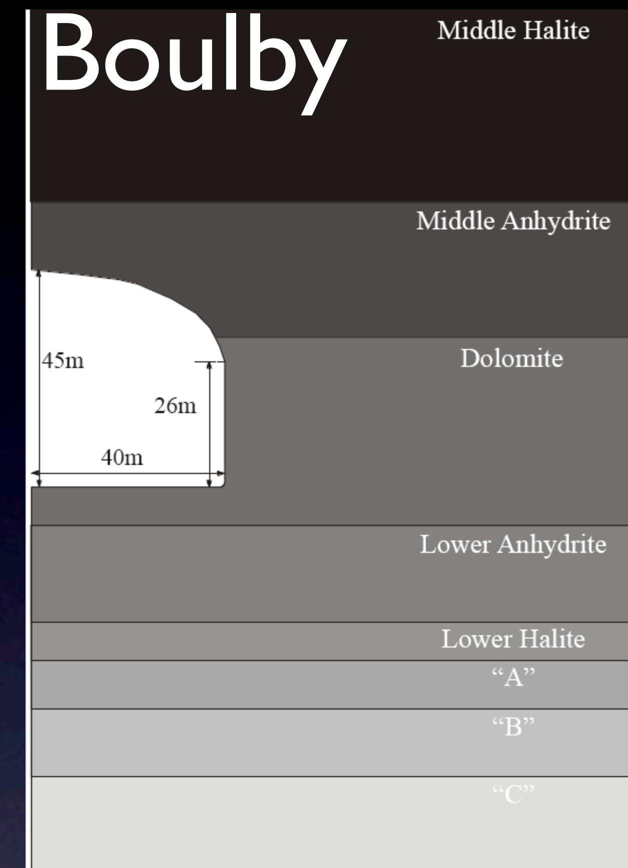


(3) Geomechanical studies

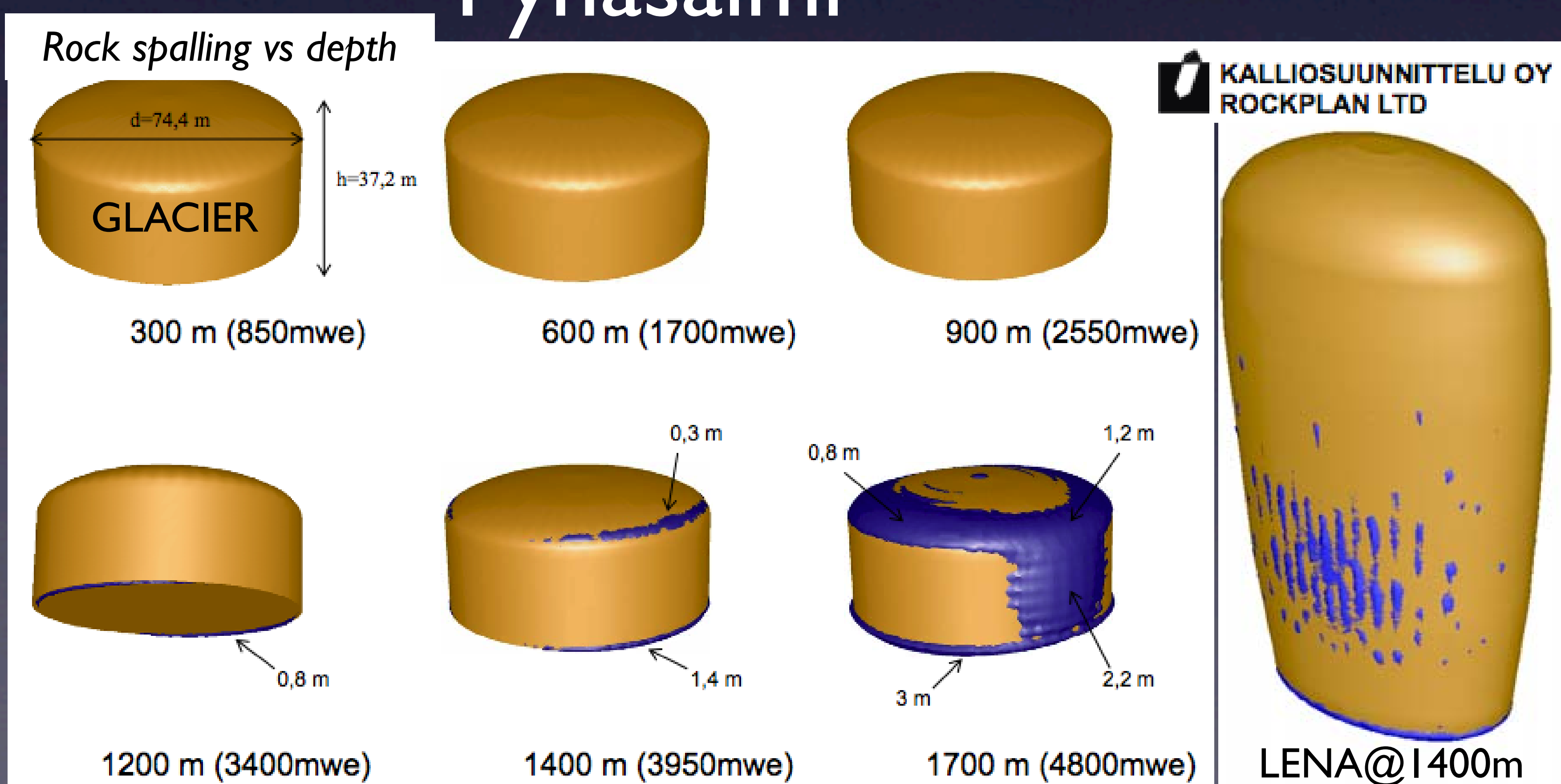
Rock data gathered for all sites
Numerical modeling based on these parameters:

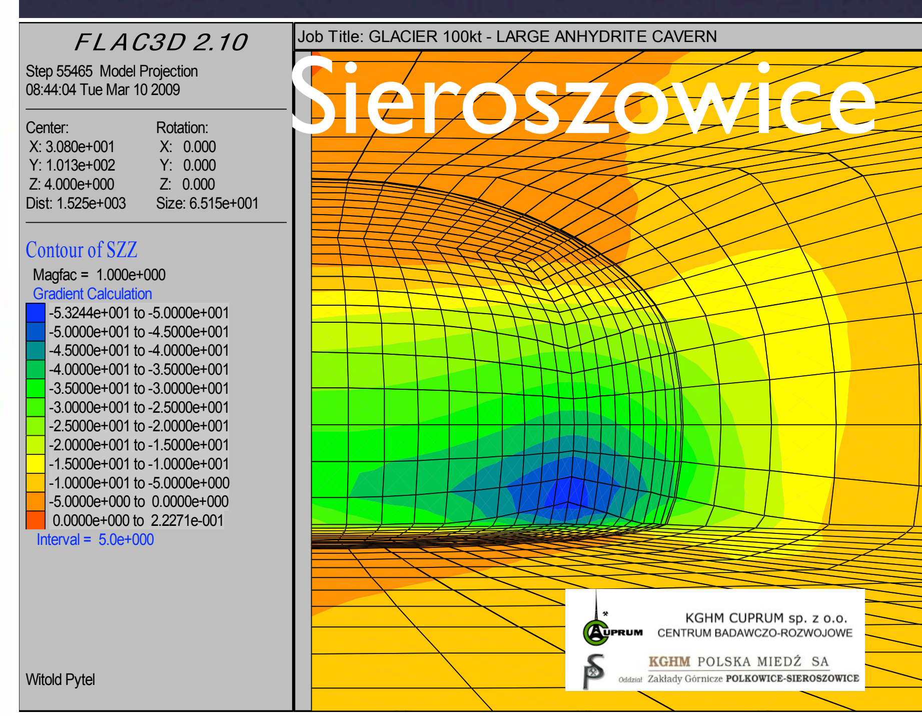
- Convergence
- Spalling
- Rock-bolting
- Mucking
- Multi-strata rock issues
- Cavern shapes





Pyhäsalmi

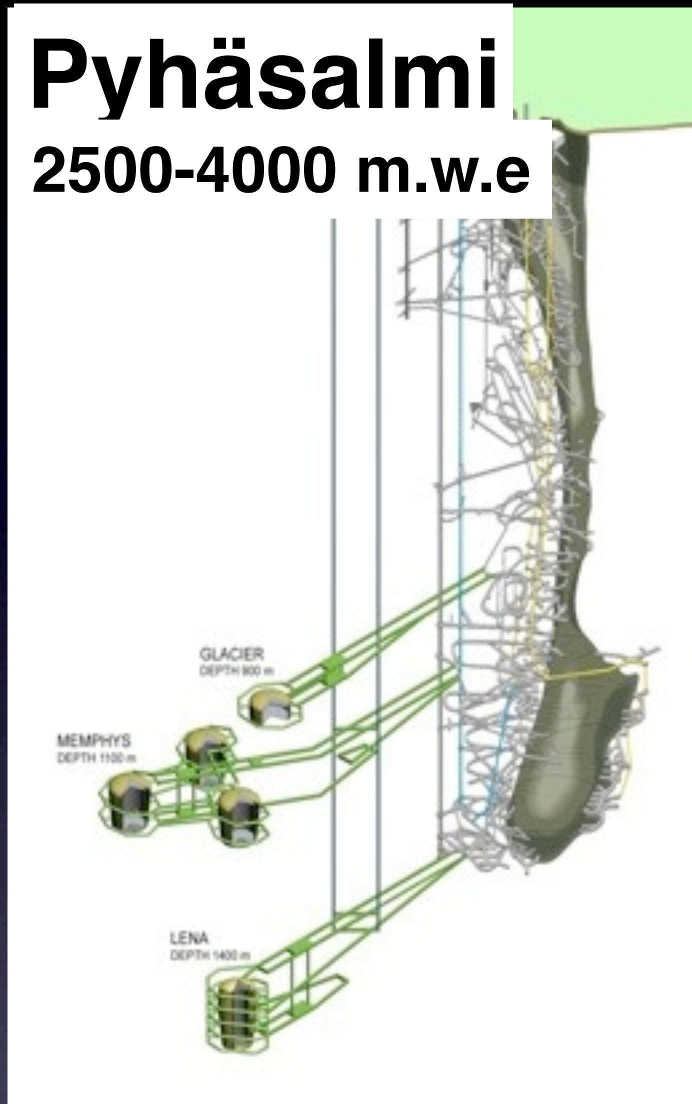




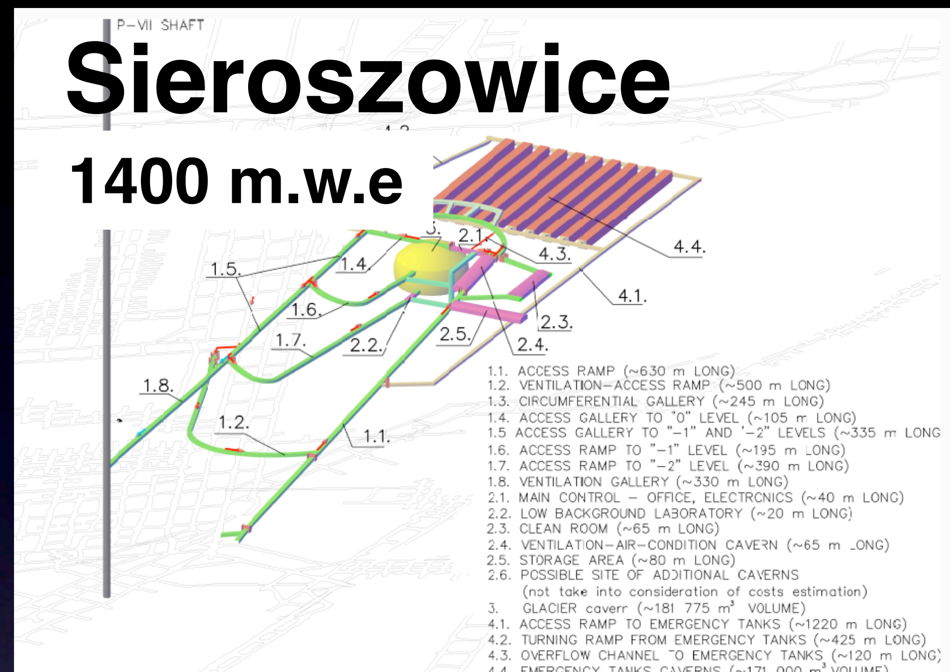
(4) Underground Layouts

Details of layout including MDC, auxilliary caverns, access, escape routes, etc...

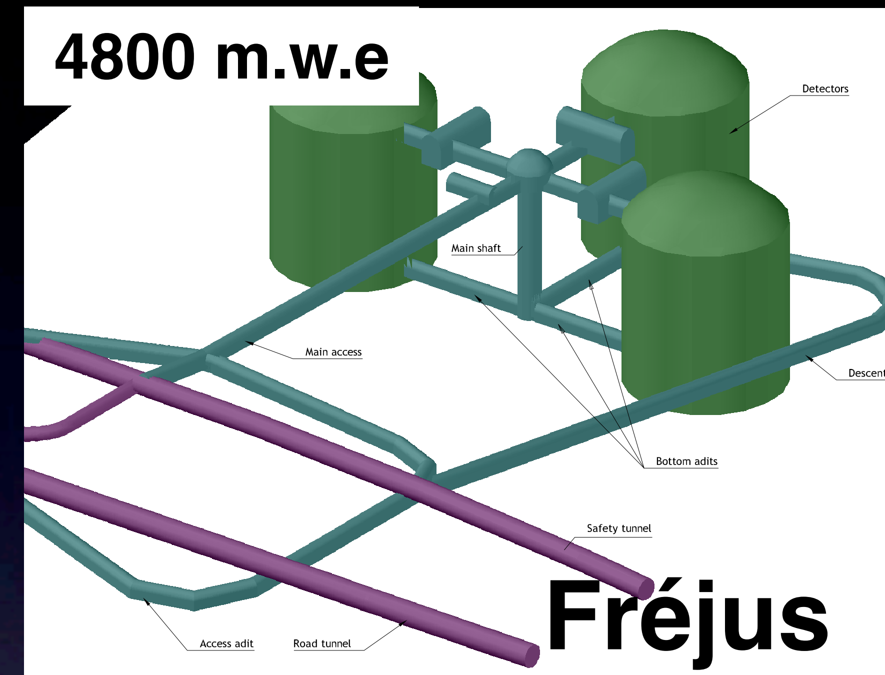
Pyhäsalmi
2500-4000 m.w.e



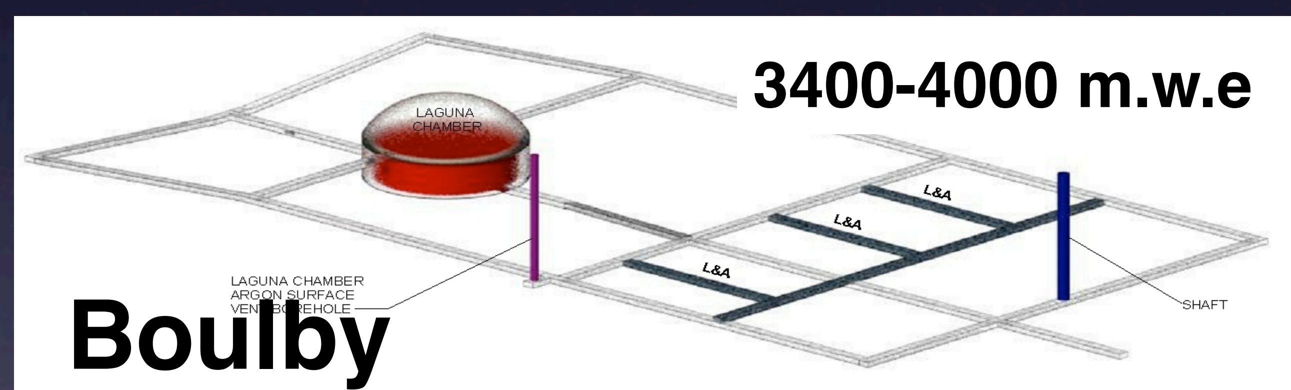
Sieroszowice
1400 m.w.e



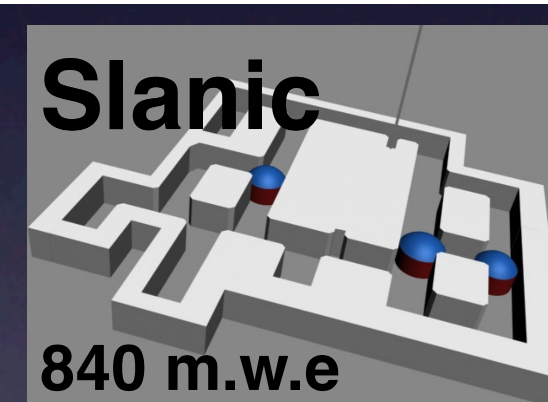
Fréjus
4800 m.w.e



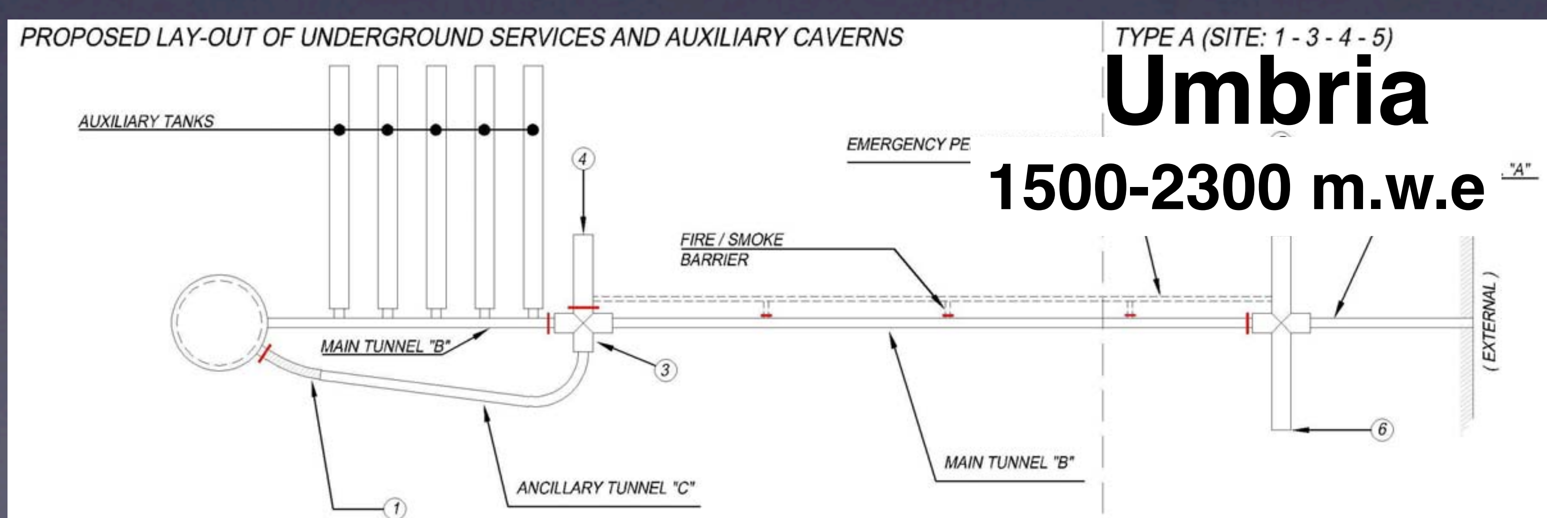
Boulby
3400-4000 m.w.e



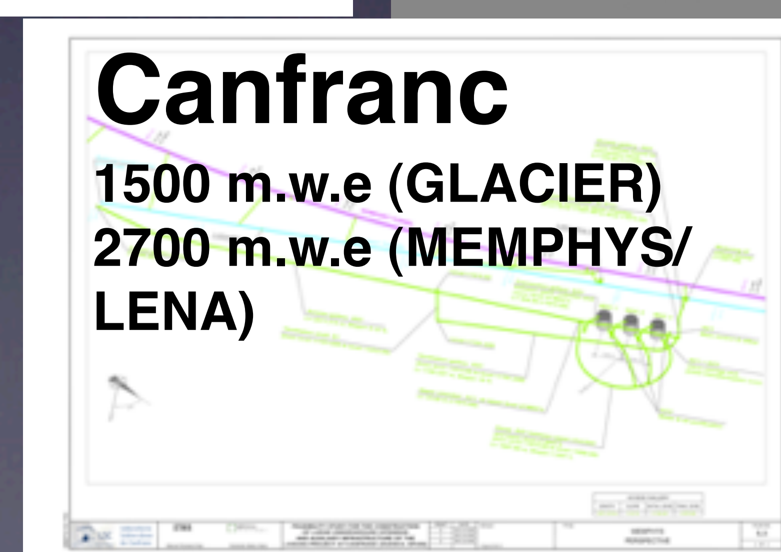
Slanic
840 m.w.e



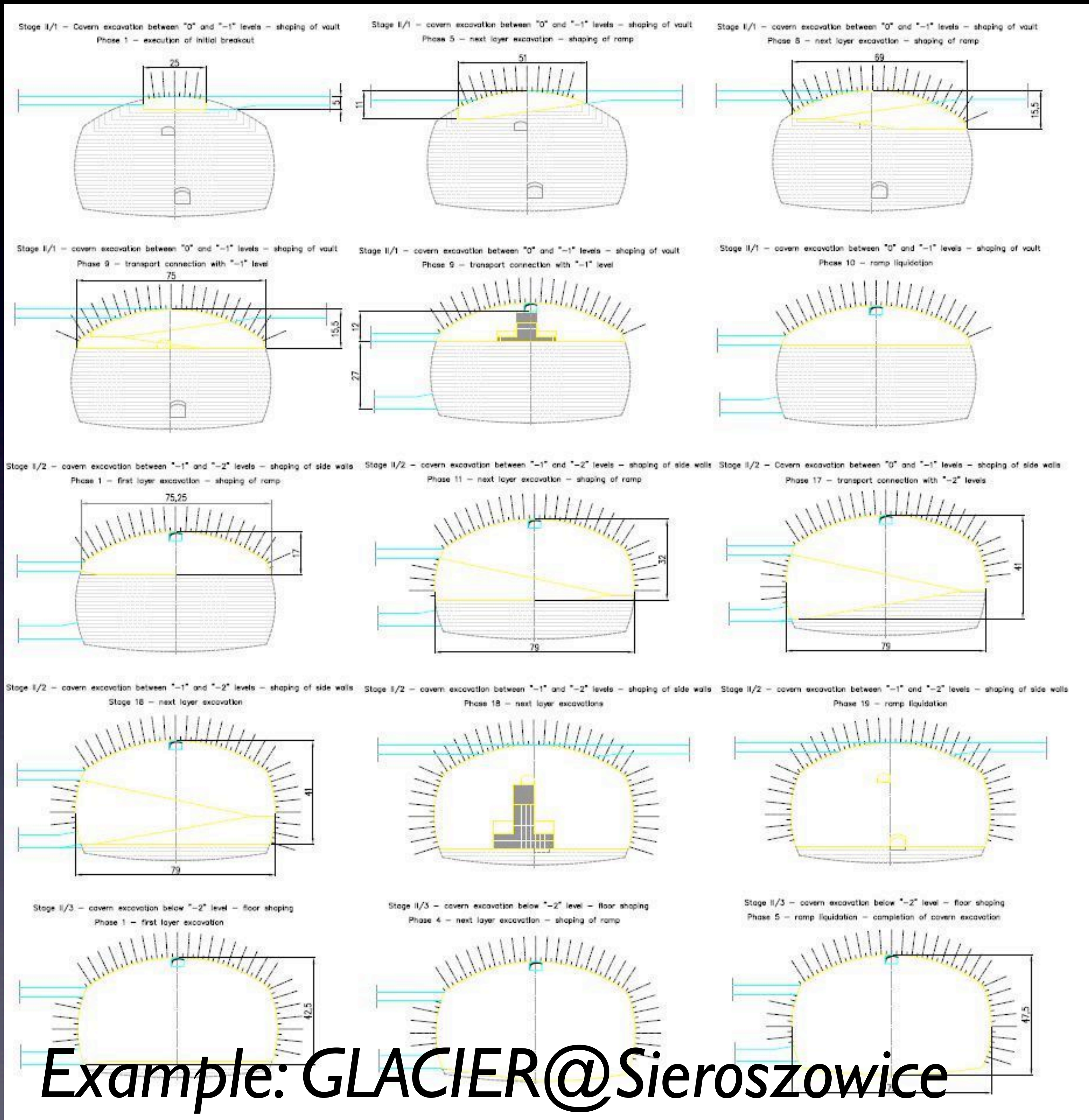
Umbria
1500-2300 m.w.e



Canfranc
1500 m.w.e (GLACIER)
2700 m.w.e (MEMPHYS/ LENA)



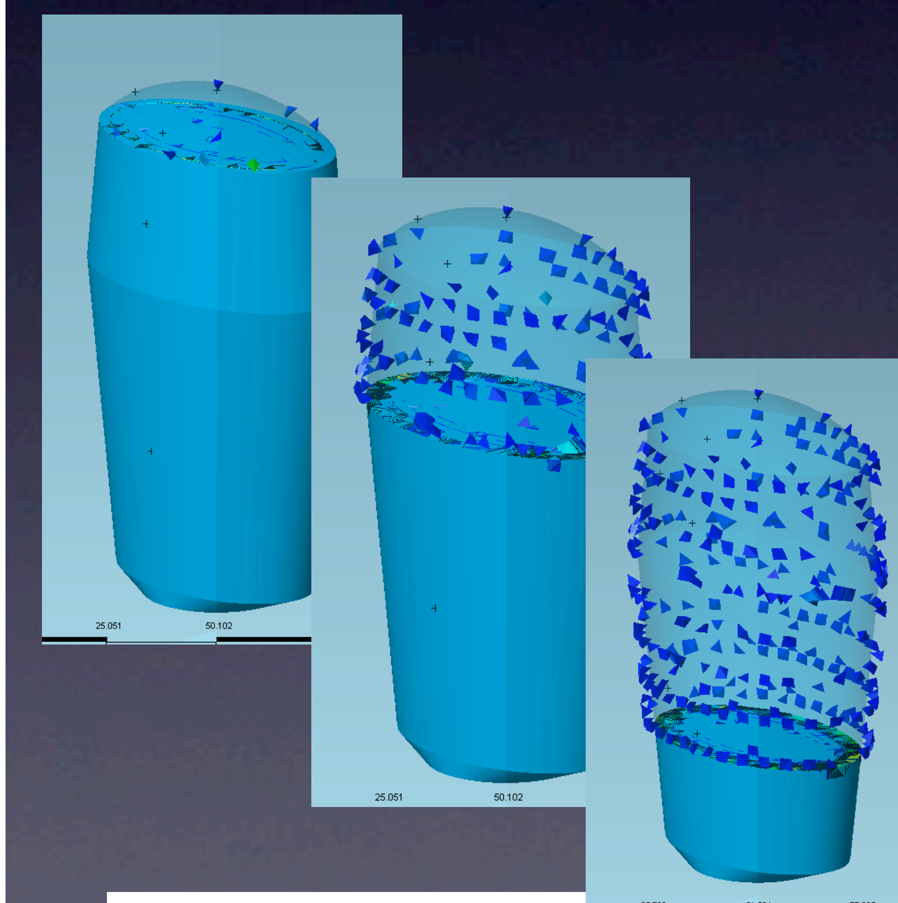
(5) Sequence of excavation



Example: GLACIER@Sieroszowice

Details of construction sequence also studied at various sites

- Rock disposal
- Geotechnical stability and safety at each stage of excavation
- Requirements for rock removal and rock bolting
- Egress routes and evacuation safety

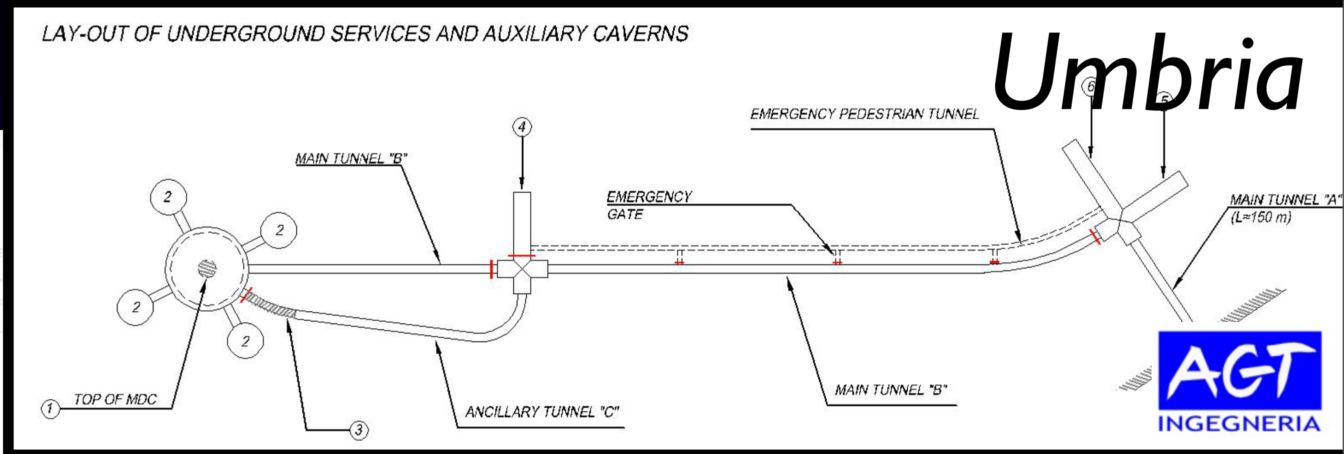


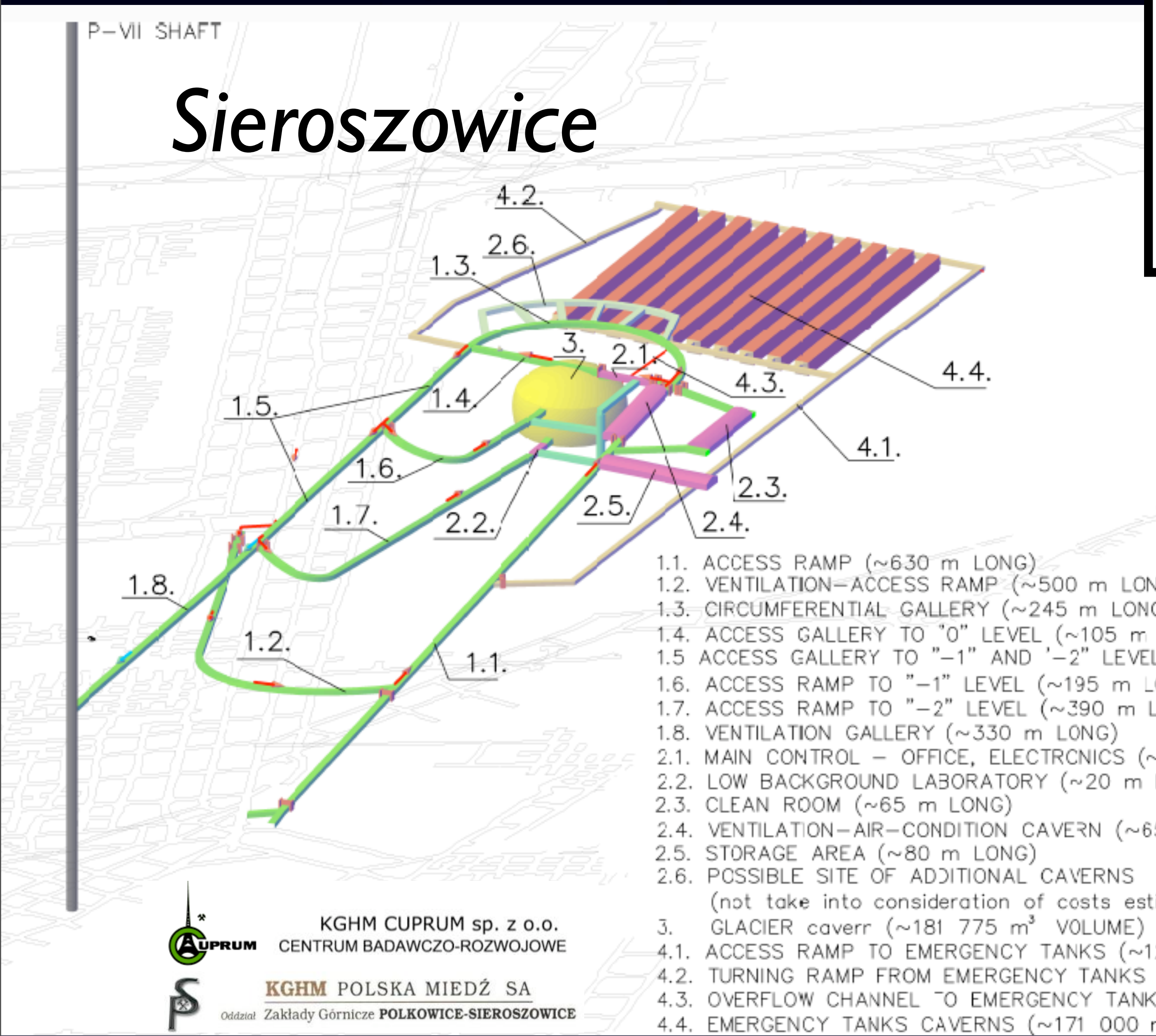
LENA@Pyhäsalmi

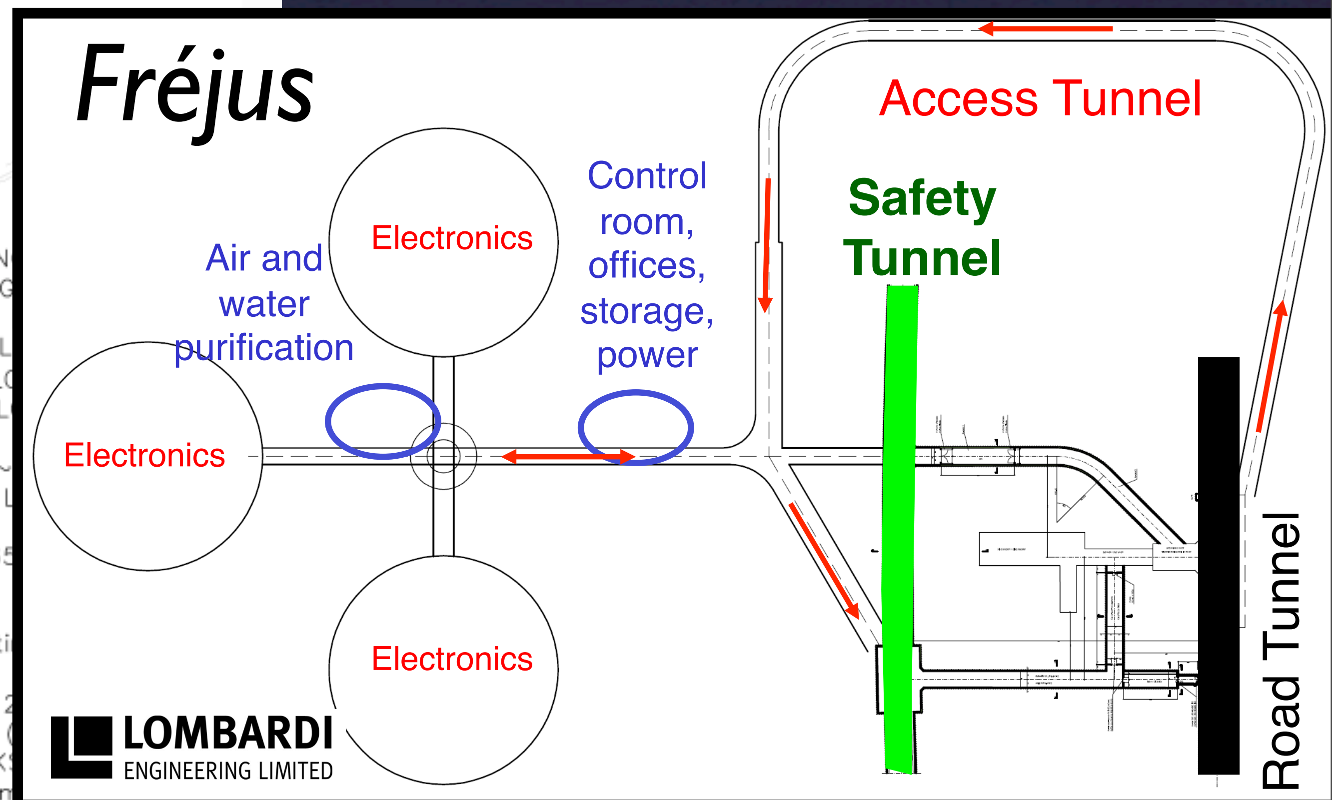
(6) Additional infrastructure

Details of ancillary laboratories, storage caverns and egress

- Design of liquid transit, storage and emergency dump
- Ancillary caverns for construction phase
- Clean rooms, electronics and mechanical workshops
- Emergency safe havens, double egress routes



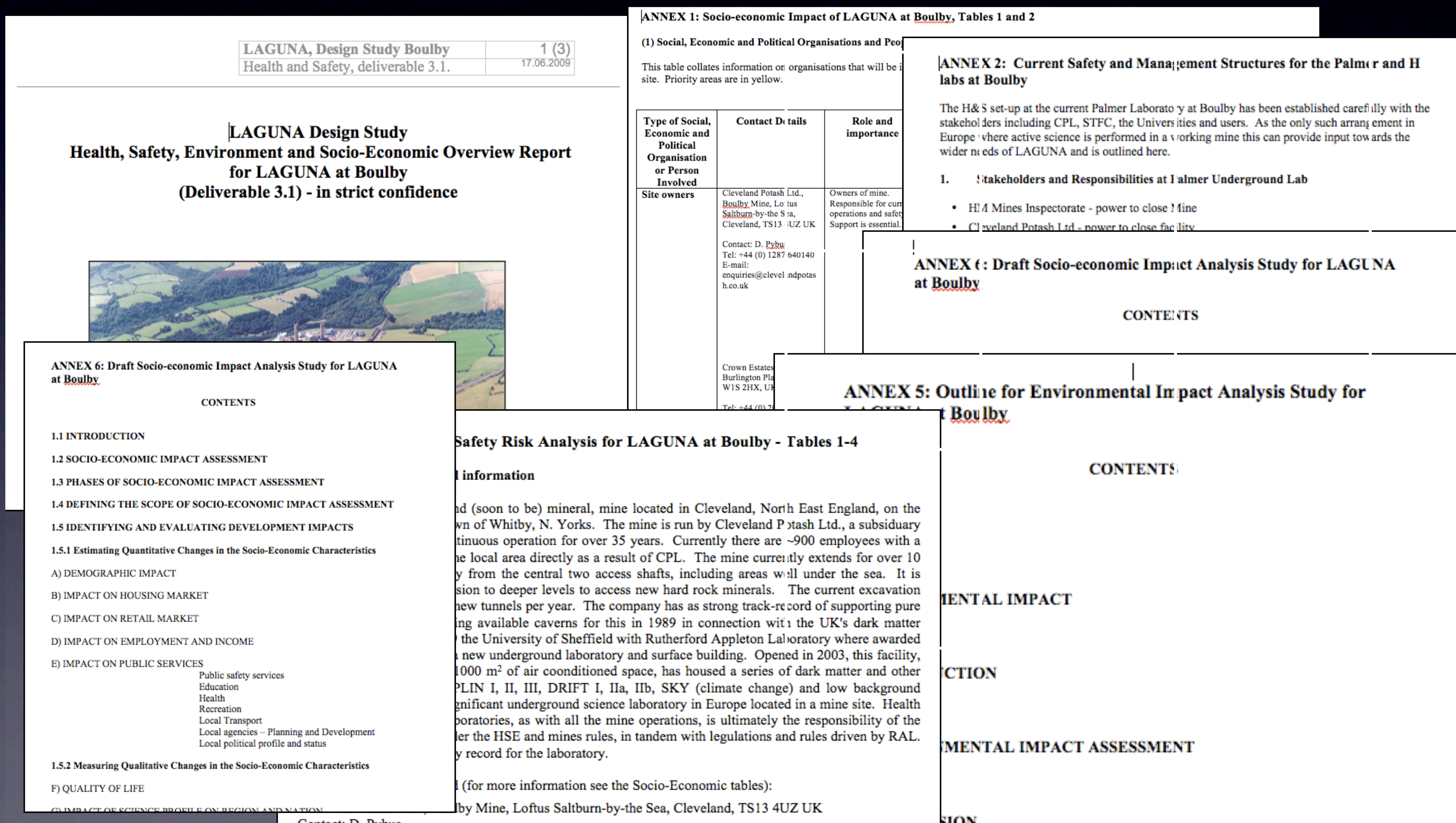




(7) Socio-Economic, Safety, Environment

Important aspect in the eyes of the EU and the funding agencies

- Socio-economic
- HAZCON (with Technodyne)
- safety, risk analysis
- environment...



Preliminary LAGUNA findings

1. All the pre-selected sites appear technically and environmentally feasible, so there are several options (unlike in Japan or now USA), though not all sites are interested in all detector options.
2. It appears technically feasible to excavate the desired underground caverns and infrastructures, to build the necessary tanks underground, and to fill them with the desired liquids.
3. The liquid procurement with the needed quantities is feasible for all sites and for all liquids (Water, LAr, LScint), although it might take several calendar years to reach the full *in-situ* procurement.
4. The cost of the excavation, although non-negligible, is not the dominant cost of the project. In order to proceed towards a technology choice, a better understanding of the costs of the full detector design and construction including their instrumentation for the three detector options is essential.
5. Studies indicate that some European options offer potential physics and/or technical advantages that need to be specially and carefully confronted with other options worldwide.
6. The physics goals play a dominant role in selecting the site !

Simplified illustration of site selection based on physics goals

		Is location important?	Is depth important ?	Comments
LAGUNA Physics goal	Neutrino properties Long Baseline exp.	Yes	No	Suitable distance from the accelerator is crucial.
	Neutrino properties Oscillometry	No	Yes	Suitable source at proper distance is crucial.
	Proton decay	No	Yes	
	High energy neutrino astrophysics	No	Yes	
	Diffuse SN neutrino background	Yes	Yes	Low neutrino background is required (far away from power reactors), large overburden is required
	Supernova neutrinos/Solar neutrinos	No	Yes	Large overburden is required to suppress cosmogenic backgrounds
	Geoneutrinos	Yes	Yes	Low neutrino background is required (far away from power reactors). High geoneutrino flux is desired.

ν beams at CERN – future possibilities

Short timescale (~2015)

- Conventional LBL ν-beams from SPS (400 GeV)
  - Exploit the CNGS technology, sub-MW class facility, **CNGS+**
    - Intensity upgrade, new focusing scheme for low ν-beam energies
- Conventional SBL ν-beam from PS (20 GeV) – **PSNF**
  - Dedicated experiment on sterile neutrinos
  - Test bed for detector and targetry R&D, x-section measurements

Medium timescale (~2020)

- Conventional LBL ν-beams from SPS (400 GeV)
  - CNGS+ beam to a new site (**CN2?**)
- Upgrade using LP-SPL as proton driver, new HPPS (30-50 GeV)
  - ~MW class facility (**CN2?-HP**)

The BIG picture – ultimate facilities (~2030)

- Super beams, β-beams, Neutrino Factory
  - HP-SPL and new accelerators, MMW class facilities

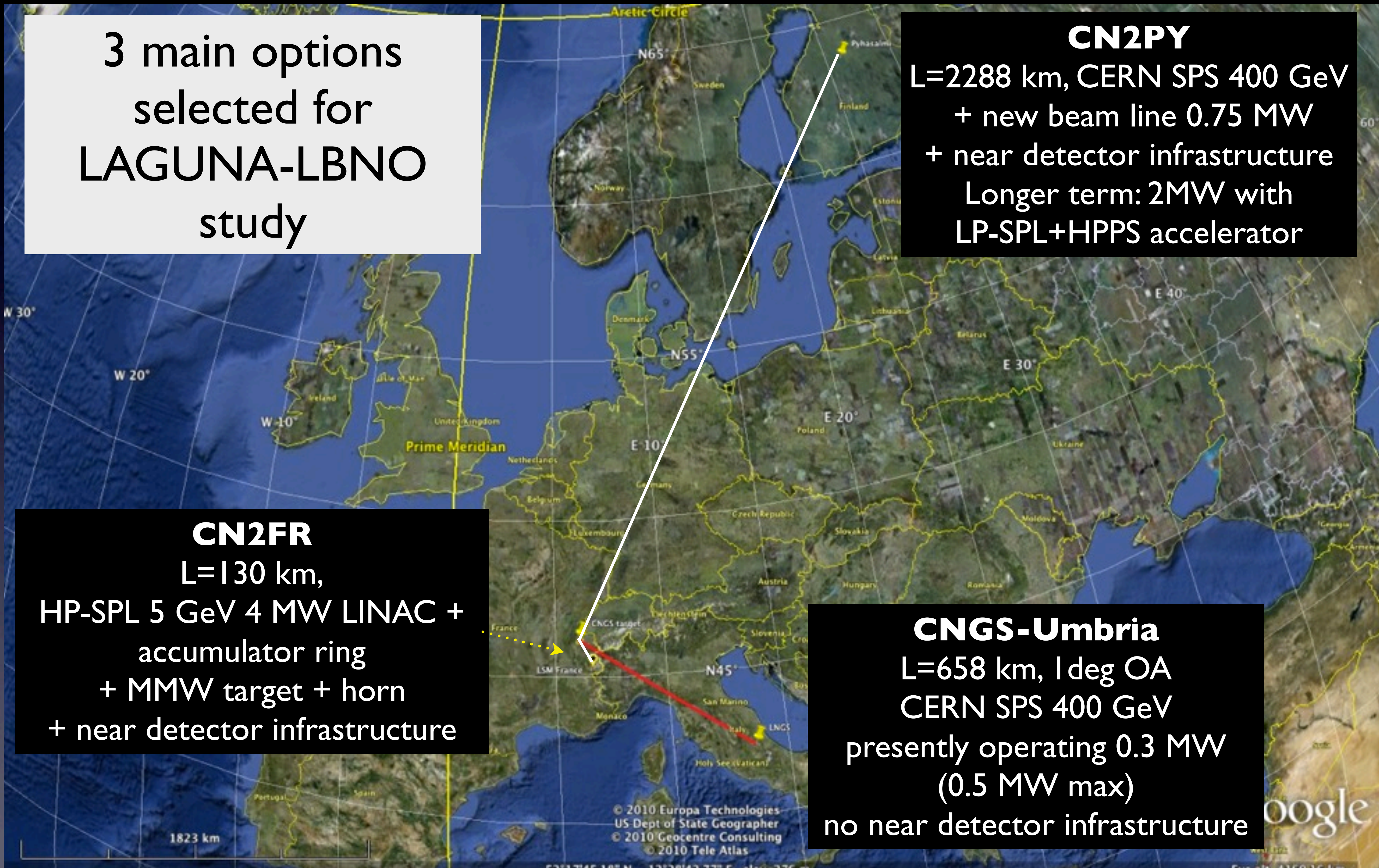
LAGUNA-LBNO options

3 main options selected for LAGUNA-LBNO study

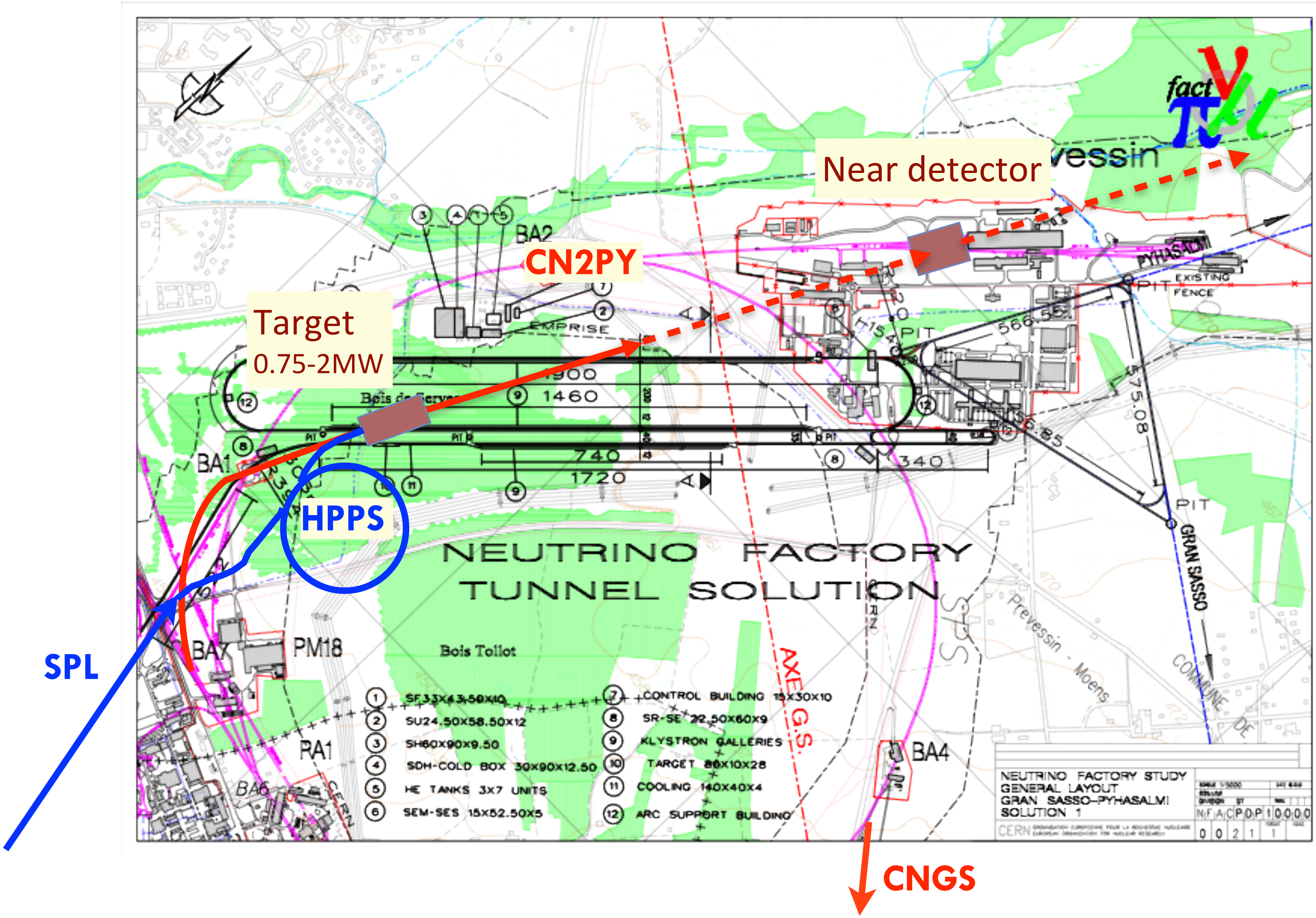
CN2PY
L=2288 km, CERN SPS 400 GeV
+ new beam line 0.75 MW
+ near detector infrastructure
Longer term: 2MW with LP-SPL+HPPS accelerator

CN2FR
L=130 km,
HP-SPL 5 GeV 4 MW LINAC + accumulator ring
+ MMW target + horn
+ near detector infrastructure

CNGS-Umbria
L=658 km, 1deg OA
CERN SPS 400 GeV
presently operating 0.3 MW
(0.5 MW max)
no near detector infrastructure

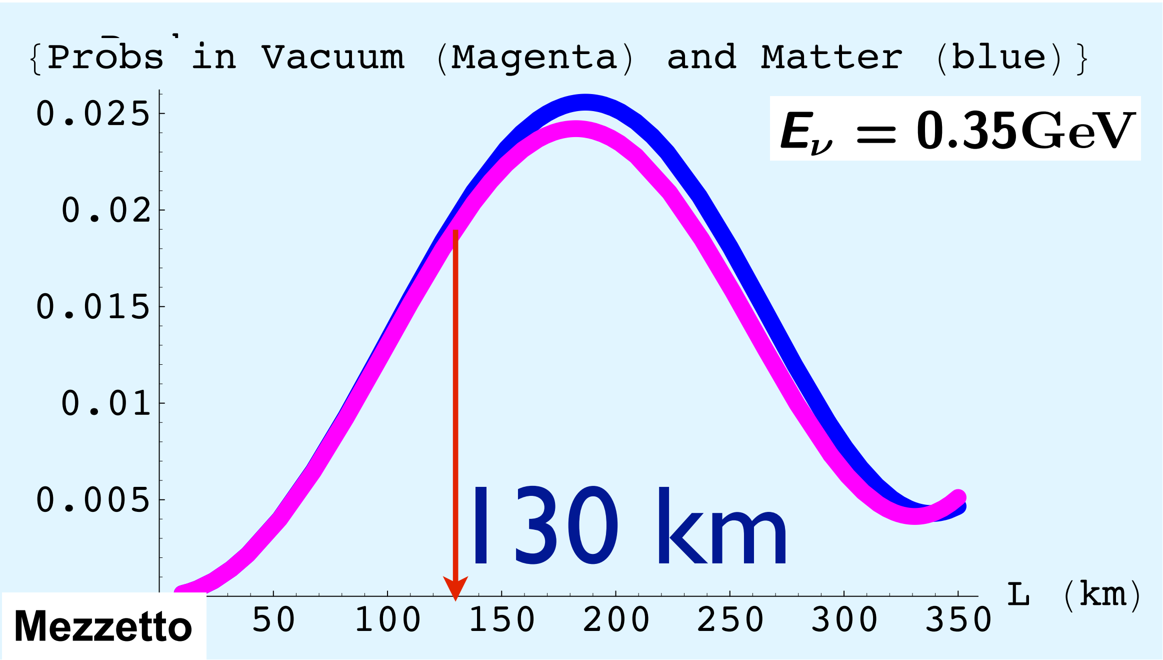


CERN ν-beam to Pyhasalmi - CN2PY



Very short/long baseline concept

CERN-Fréjus offers a very short baseline not considered elsewhere in the world ➠ unique physics opportunities in Europe

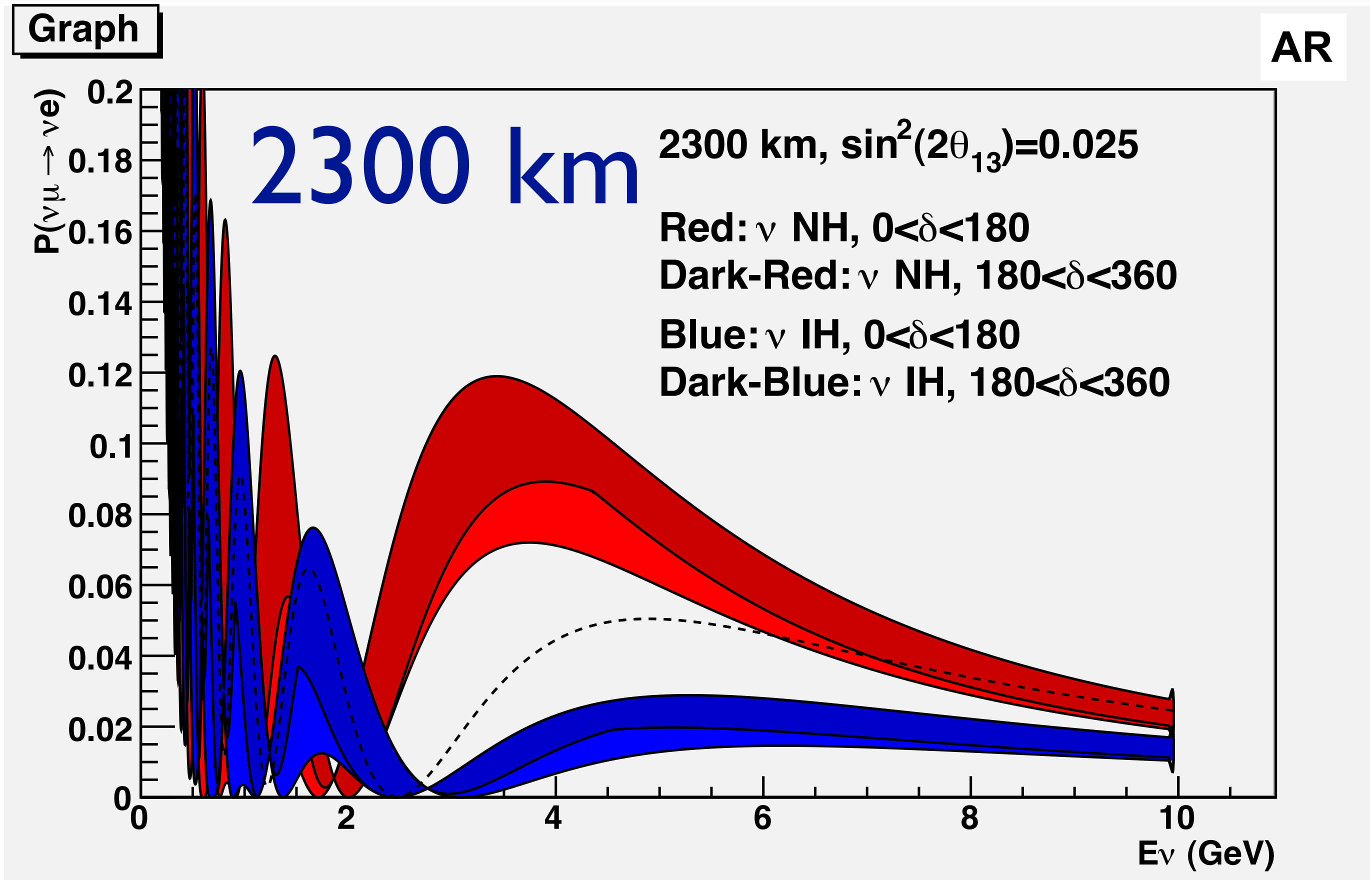


Determine CPV by comparison of neutrinos/ antineutrinos in absence of competing matter effects

need very low energy beam and huge detector

Adequate baseline/energy for betabeam

CERN-Pyhäsalmi offers a very long baseline not considered elsewhere in the world ➠ unique physics opportunities in Europe

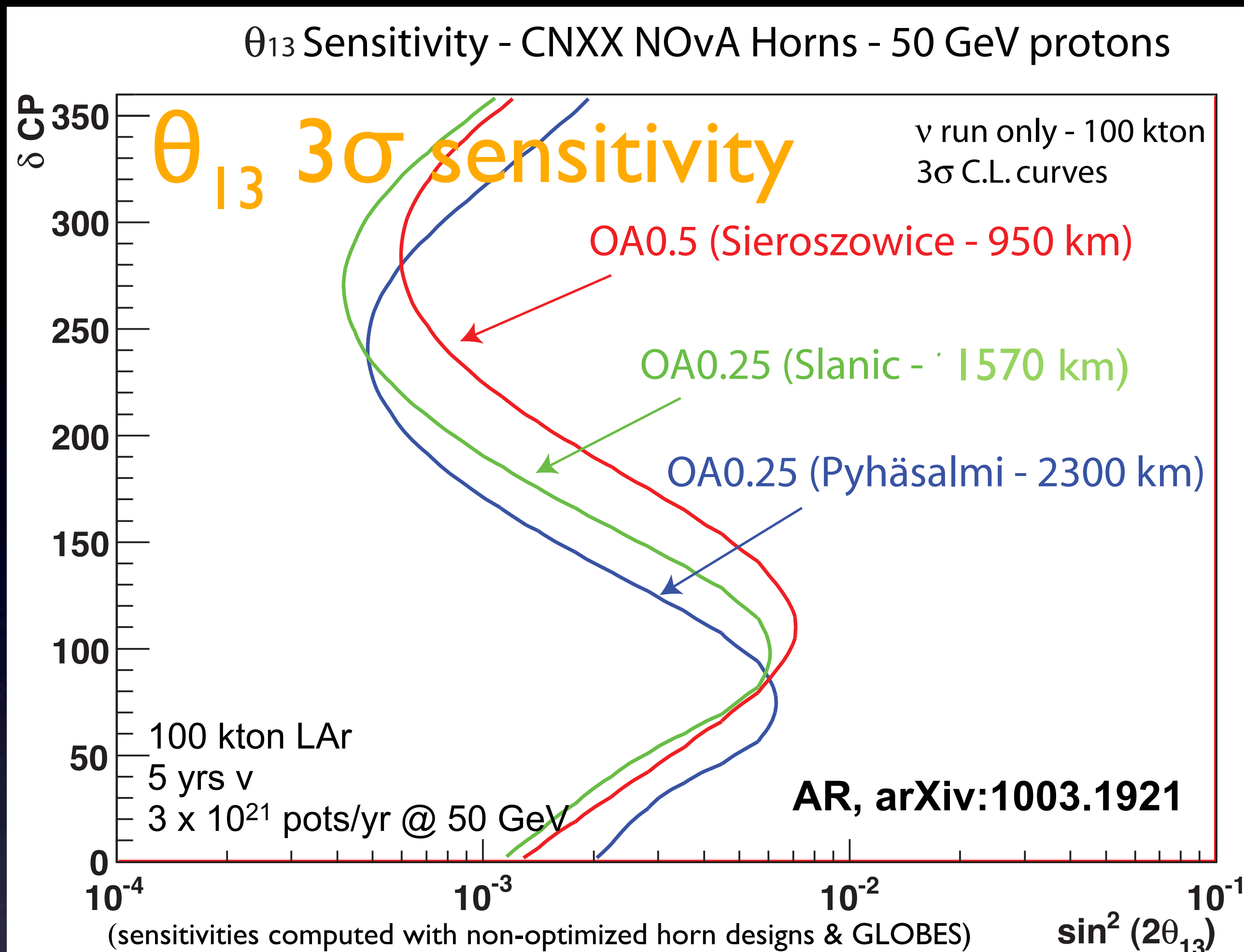


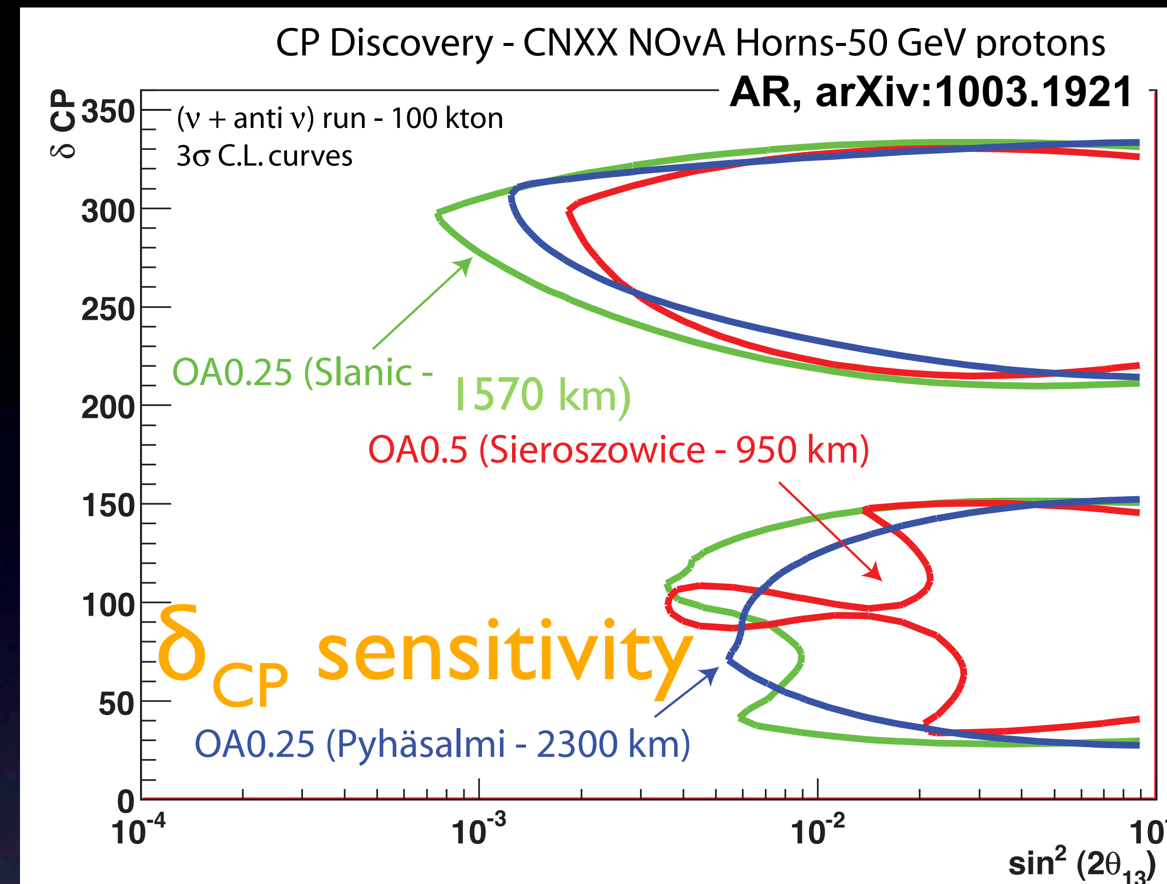
Determine CPV and mass hierarchy by spectrum measurement and resolve degeneracies and so-called "π-transit" effect

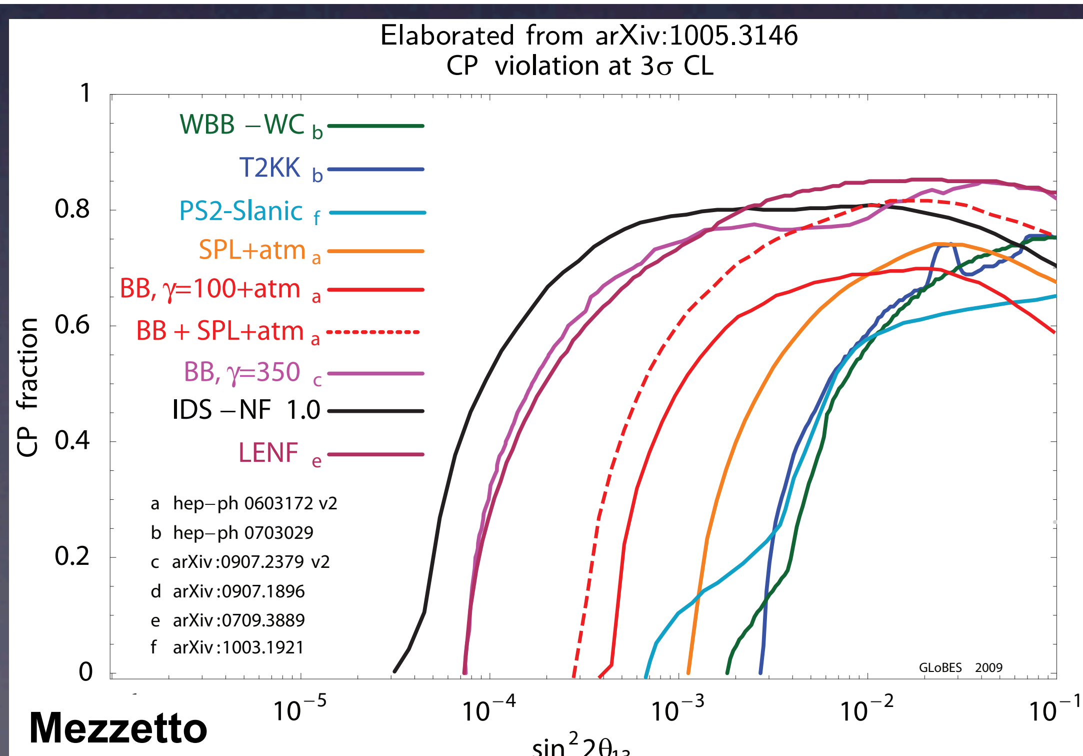
arXiv:0908.3741v1 for "Magic distance"

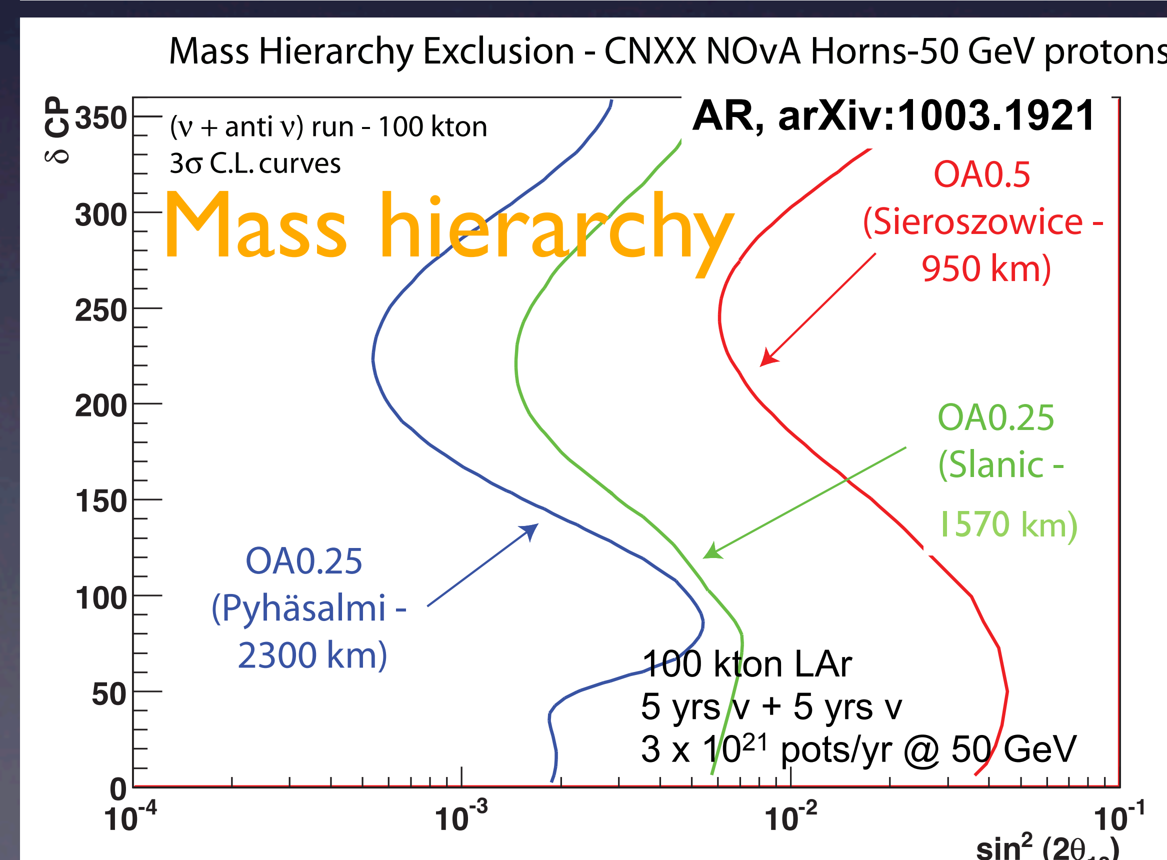
Adequate baseline for neutrino factory

Outstanding LBL ν physics goals (II)









LAGUNA - Schedule

Paper Design Study (EU funded):	2008-2011
Categorize the sites and down-select:	Sept. 2010
Study detector design and beam options (LAGUNA-LBNO submitted to EU):	2011-2014
Critical decision (and $\theta_{13}\neq 0$?)	2014 ?
Phase 1 excavation-construction:	2015-2020 ?
Phase 2 excavation-construction:	>2020 ?

Timeline matched to new potential CERN neutrino (super)beams in >2016

Conclusions

Growing worldwide interest and activities on next-generation underground large neutrino and proton decay detectors, both new sites and detector technologies

In Europe LAGUNA has a well defined roadmap & timeline
- a large amount of technical expertise has been gathered to reach the conclusions and a strong collaboration has developed since 2008
- no obvious geo-technical show-stoppers so far - but several challenges (e.g. cost of deep underground construction, liquid procurement, financing...)
- prioritize sites in 2010, study perspectives for LBL, detector technology choice

Big range of CERN baselines are feasible (130 km - 2300 km)
- includes possibility of very short and very long baselines
- LAGUNA timeline matched to conventional beam from CERN
- LAGUNA detector to be eventually operated/upgraded in connection with advanced exotic beams (>2025 ?) ?

LAGUNA mainly towards a European research infrastructure but strongly linked to projects world-wide that consider same physics goals (future J-PARC and LBNE)
- this is the only winning strategy

Next LAGUNA General meeting: CERN, March 3-4, 2011

Acknowledgements

- FP7 Research Infrastructure “Design Studies” LAGUNA (Grant Agreement No. 212343 FP7-INFRA-2007-1)

Backup slides

Event rates at Pyhäsalmi vs Okinoshima

At L=2300 km the first maximum is above tau production threshold yielding a copious number of (QEL) tau events

	Neutrino horn polarity				Antineutrino horn polarity			
Distance/OA	ν_μCC ($\bar{\nu}_\mu$CC)	ν_eCC ($\bar{\nu}_e$CC)	$\nu_\mu \to \nu_e$ ($\bar{\nu}_\mu \to \bar{\nu}_e$)	$\nu_\mu \to \nu_\tau$ ($\bar{\nu}_\mu \to \bar{\nu}_\tau$)	ν_μCC ($\bar{\nu}_\mu$CC)	ν_eCC ($\bar{\nu}_e$CC)	$\nu_\mu \to \nu_e$ ($\bar{\nu}_\mu \to \bar{\nu}_e$)	$\nu_\mu \to \nu_\tau$ ($\bar{\nu}_\mu \to \bar{\nu}_\tau$)
J-PARC , 30 GeV protons , 1.66 MW								
Okinoshima **658 km** 0.76 deg	17010 (619)	138 (12)	26 (0.4)	1.5 (0.2)	1817 (4627)	32 (31)	1.3 (5.4)	0.5 (0.4)
CNXX NUMI-ME-like horns , 400 GeV SPS protons , 2.4$\times 10^{20}$ pot/year								
Pyhäsalmi **2300 km** 0.25 deg	12393 (449)	73 (10)	26 (0.3)	297 (16)	738 (4808)	15 (25)	1.2 (4.1)	28 (115)
CNXX NUMI-ME-like horns , 50 GeV HPPS2 protons , 3$\times 10^{21}$ pot/year								
Pyhäsalmi **2300 km** 0.25 deg	10655 143	72 3	47 0.2	80 3	596 2906	9 19	1.8 5.5	14 16

JPARC MR

SPS

HP-PS'

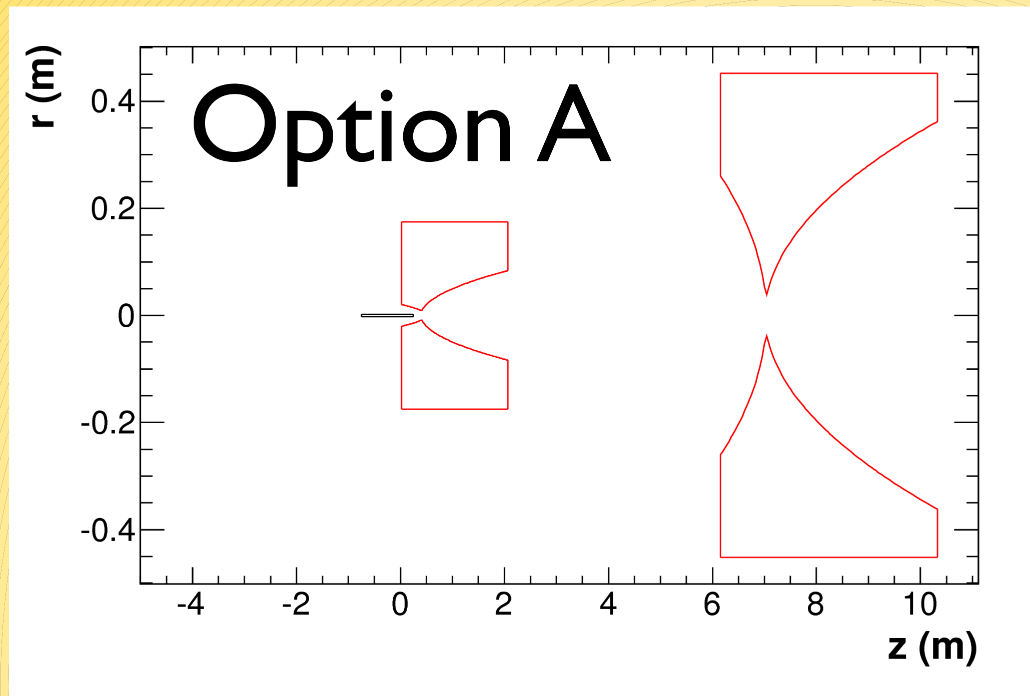
Table 1: Charged current (CC) event rate calculated for J-PARC assuming the T2K optics and for CNXX using a NUMI-ME-like realistic focusing, normalized for one year and a liquid Argon detector with a mass of 100 kton. We assume for the mixing angles $\tan 2\theta_{12} = 0.45$, $\theta_{23} = \pi/4$ and $\sin^2 2\theta_{13} = 0.002$.

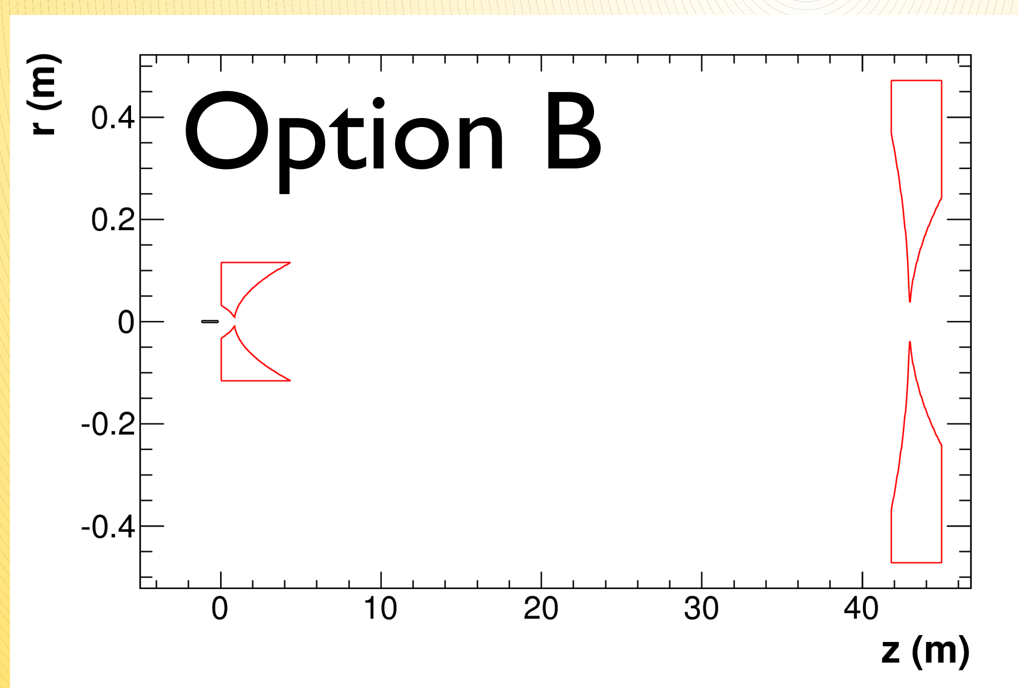
GEANT4 simulations of fluxes

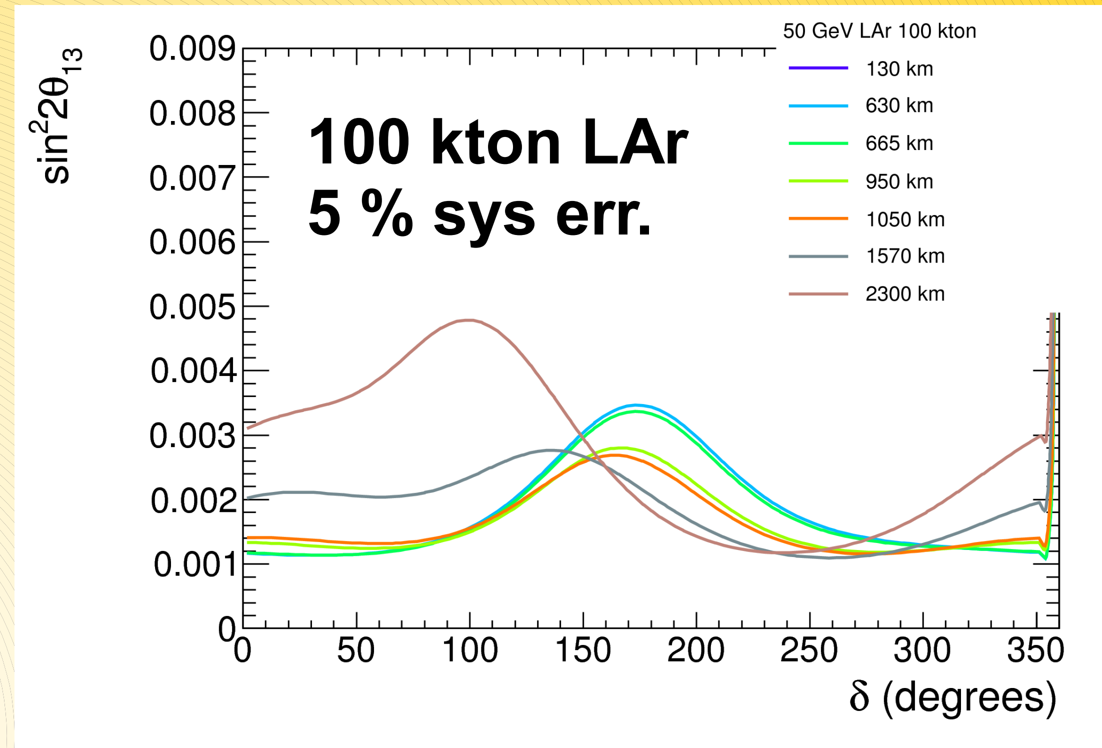
A. Longhin

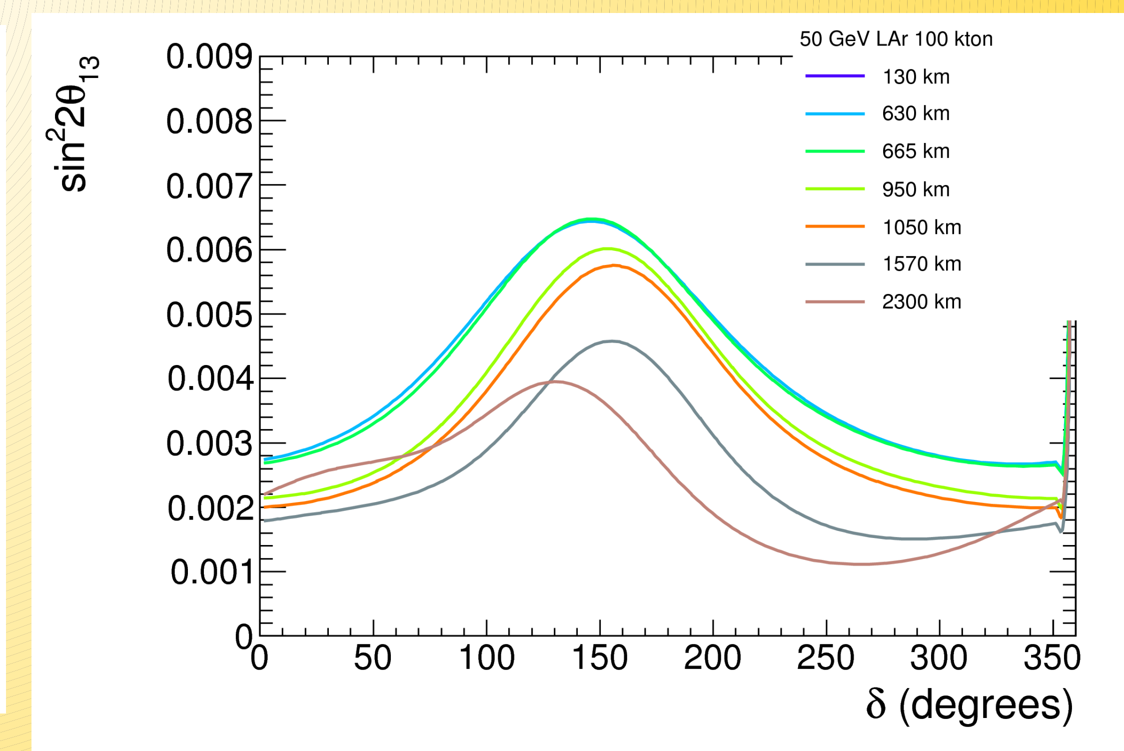
The GEANT4 simulation and optimization tools are being used to study Super Beams from a 50 GeV proton driver ("HP-PS2") to LAGUNA sites equipped with a 100 kton LAr detector

study ongoing within the LAGUNA-WP2 (physics)







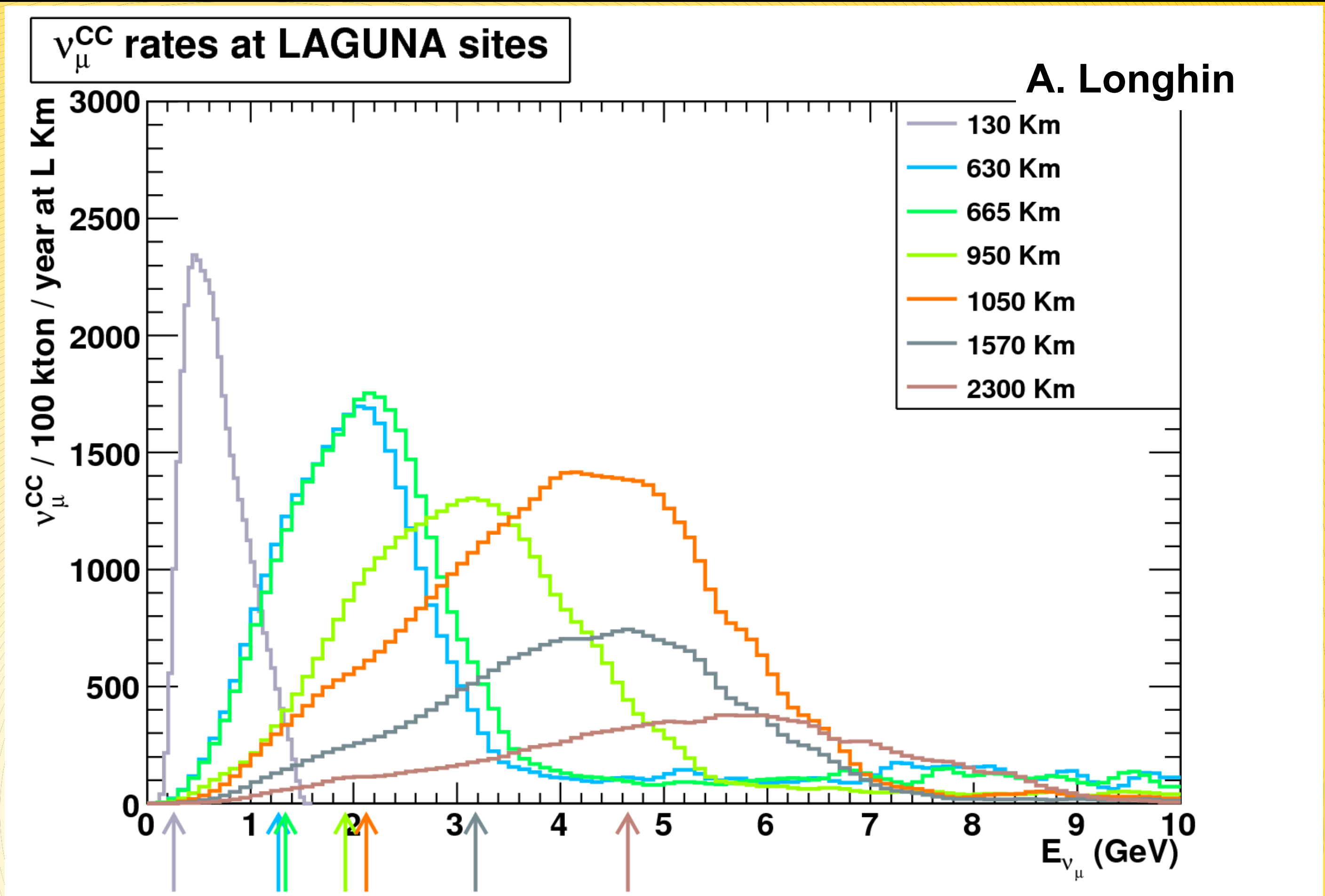


Fluxes full optimization vs baseline

ν_μ^{CC} rates

at "L" Km
for 1 year running
on a 100 kton mass

Two effects:
- N ~ σ(E) ~ E
- N ~ $1/L^2$

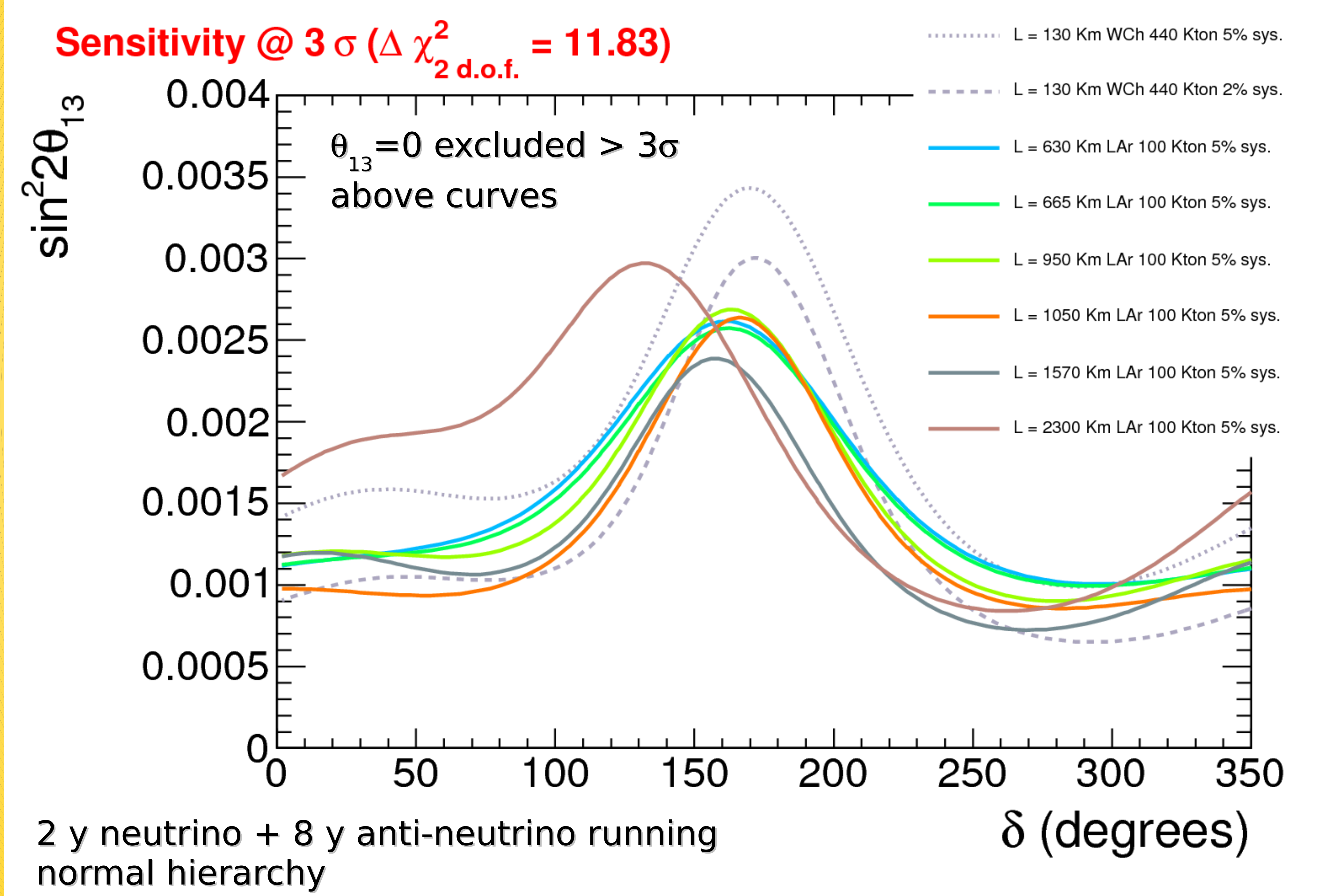


	ν run			$\bar\nu$ run		
L (km)	$\nu_\mu^{CC}(\bar\nu_\mu^{CC})$	$\nu_e^{CC}(\bar\nu_e^{CC})$	$\frac{\nu_e+\bar\nu_e}{\nu_\mu+\bar\nu_\mu}$ (%)	$\nu_\mu^{CC}(\bar\nu_\mu^{CC})$	$\nu_e^{CC}(\bar\nu_e^{CC})$	$\frac{\nu_e+\bar\nu_e}{\nu_\mu+\bar\nu_\mu}$ (%)
130	41316 (94)	174 (2)	0.42	527 (5915)	12 (15)	0.42
630	36844 (2903)	486 (95)	1.5	7930 (13652)	270 (157)	2.0
665	38815 (2967)	516 (96)	1.5	7516 (14287)	280 (158)	2.0
950	37844 (1363)	349 (48)	1.0	3504 (14700)	110 (107)	1.3
1050	51787 (761)	314 (23)	0.64	1964 (21728)	54 (88)	0.60
1570	26785 (385)	174 (10)	0.67	945 (11184)	22 (47)	0.57
2300	17257 (203)	110 (7)	0.67	471 (7577)	16 (32)	0.60

A. Longhin LAGUNA meeting Modane 6-9 Sept 2010

Sensitivity comparison for all sites

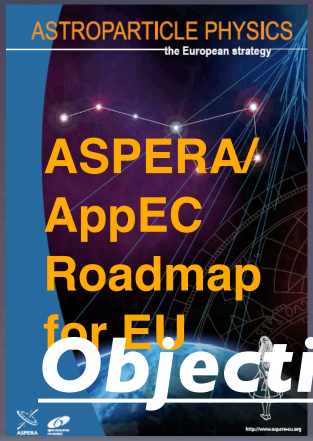
Sensitivity limit on $\sin^2 2\theta_{13}$



A. Longhin LAGUNA meeting Modane 6-9 Sept 2010

A new giant neutrino observatory in Europe ?

- **Advances in low energy neutrino astronomy and direct investigation of Grand Unification require the construction of very large volume underground observatories.**
- There is currently no such infrastructure in Europe able to host underground instruments of this size, although five national underground laboratories with high technical expertise are currently operated with leading-edge smaller-scale underground experiments.
- A pan-European infrastructure able to host underground instruments with volumes at the 100’000 m^3 scale will provide new and unique scientific opportunities in low energy neutrino astronomy and Grand Unification physics.
- This field of research is at the forefront of particle and astro-particle physics and is the subject of intense investigation also in North America and Asia. Such an infrastructure in Europe would attract scientists from all over the world and ensure that Europe will continue to play a leading and innovative role in the field.



ASPERA/AppEC Roadmap for EU

“recommend that a new large European infrastructure is put forward as a future international multi-purpose facility on the 100-1000 ktons scale for improved studies of proton decay….”

⇒ **LAGUNA project**

Objective: defining and realizing this research programme in Europe

LAGUNA consortium

Large Apparatus for Grand Unification and Neutrino Astrophysics

The LAGUNA consortium†: *D. Angus[a], A. Ariga[b], D. Autiero[c], A. Apostu[d], A. Badertscher[e], T. Bennet[f], G. Bertola[g], P.F. Bertola[g], O. Besida[h], A. Bettini[i], C. Booth[f], J.L. Borne[c], I. Brancus[d], W. Bujakowsky[j], J.E. Campagne[c], G. Cata Danil[d], F. Chipesiu[d], M. Chorowski[k], J. Cripps[f], A. Curioni[e], S. Davidson[c], Y. Declais[c], U. Drost[g], O. Duliu[l], J. Dumarchez[c], T. Enqvist[m], A. Ereditato[b], F. von Feilitzsch[n], H. Fynbo[o], T. Gamble[f], G. Galvanin[p], A. Gendotti[e], W. Gizicki[k], M. Goger-Neff[n], U. Grasslin[g], D. Gurney[q], M. Hakala[r], S. Hannestad[o], M. Haworth[q], S. Horikawa[e], A. Jipa[l], F. Juget[b], T. Kalliokoski[s], S. Katsanevas[c], M. Keen[t], J. Kisiel[u], I. Kreslo[b], V. Kudryastev[f], P. Kuusiniemi[m], L. Labarga[v], T. Lachenmaier[n], J.C. Lanfranchi[n], I. Lazanu[l], T. Lewke[n], K. Loo[m], P. Lightfoot[f], M. Lindner[w], A. Longhin[h], J. Maalampi[s], M. Marafini[c], A. Marchionni[e], R.M. Margineanu[d], A. Markiewicz[y], T. Marrodan-Undagoita[n], J.E. Marteau[c], R. Matikainen[r], Q. Meindl[n], M. Messina[b], J.W. Mietelski[y], B. Mitrica[d], A. Mordasini[g], L. Mosca[h], U. Moser[b], G. Nuijten[r], L. Oberauer[n], A. Oprina[d], S. Paling[f], S. Pascoli[a], T.Patzak[c], M. Pectu[d], Z. Pilecki[j], F. Piquemal[c], W. Potzel[n], W. Pytel[x], M. Raczynski[x], G. Rafflet[z], G. Ristaino[p], M. Robinson[f], R. Rogers[q], J. Roinisto[r], M. Romana[i], E. Rondio[A], B. Rossi[b], A. Rubbia[e], Z. Sadecki[x], C. Saenz[i], A. Saftoiu[d], J. Salmelainen[r], O. Sima[l], J. Slizowski[j], K. Slizowski[j], J.Sobczyk[B], N. Spooner[f], S. Stoica[d], J. Suhonen[s], R.Sulej[A], M. Szarska[y], T. Szeglowski[B], M. Temussi[p], J. Thompson[q], L. Thompson[f], W.H. Trzaska[s], M. Tippmann[n], A. Tonazzo[c], K. Urbanczyk[j], G. Vasseur[h], A. Williams[t], J. Winter[n], K. Wojutszewska[j], M. Wurm[n], A. Zalewska[y], M. Zampaolo[c], M.Zito[h]*

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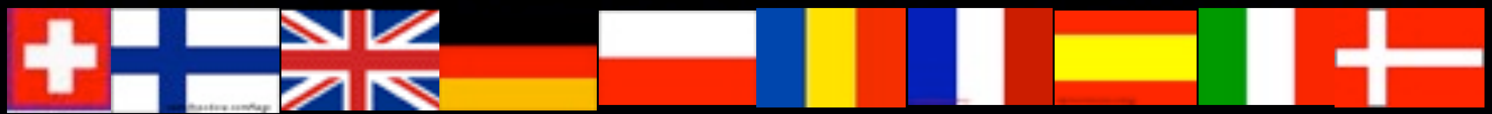

- European physicists interested in massive neutrino detectors; geo-technical experts, geo-physicists; structural engineers; tank, rock mechanical&underground and mining engineers
- about 100 members
- 28 institutions
- 10 countries
- multidisciplinary
- academic and industrial partners

http://www.laguna-science.eu/

***Objective**: defining and realizing this research programme in Europe*

16 deliverables (2008-2011)

Deliverable Number 61	Deliverable Title	WP number 53	Lead beneficiary number	Estimated indicative person-months	Nature 62	Dissemination level 63	Delivery date 64
1.1	First year report	1	ETHZ	5	Report	Public	12
1.2	Final report on European underground research infrastructure and its science	1	ETHZ	10	Report	Public	24
2.1	Interim report for CUPP/ Pyhäsalmi	2	UOULU	18	Report	Public	16
2.2	Interim report for Fréjus	2	CNRS	18	Report	Public	16
2.3	Interim report for Boulby	2	USFD	18	Report	Public	16
2.4	Interim report for CNGS off-axis	2	U-Bern	10	Report	Public	16
2.5	Interim report for SUNLAB	2	IFJ PAN	18	Report	Public	16
2.6	Interim report for LSC	2	LSC	18	Report	Public	16
2.7	Interim report for IFIN-HH	2	IFIN-HH	10	Report	Public	16
2.8	Final joint report on potential European sites	2	UOULU	20	Report	Public	24
3.1	Site specific safety overview report	3	USFD	20	Report	CO	12
3.2	Final report on safety	3	USFD	20	Report	CO	24
3.3	Report on liquid procurement	3	USFD	10	Report	RE	20
3.4	Report on socio-economic impact	3	USFD	10	Report	RE	20
4.1	Deep science paper for general audience	4	IFJ PAN	20	Report	Public	24
4.2	Scientific paper for the physics community	4	IFJ PAN	20	Report	Public	24
			Total	245			

green=delivered, yellow=almost ready

(7) Excavation cost estimates

Cost estimation for each detector option has been divided into several sections

- Main Detector Cavern excavation and support.
- Access galleries, auxiliary caverns and ventilation facilities excavations and support.
- Installations: construction installations, underground installations and surface installations.
- Environmental measures.

- The proposed designs developed by each industrial partner for each site has been critically reviewed by the other industrial partners during a series of dedicated (and lively!) technical meetings.
- The designs were "corrected/amended" where necessary. Technical differences between sites remain due to local boundary conditions (quality of rock, depth, etc.)
- The unit costs were taken using reference from civil construction in the same area. Unit costs were debated at length. Differences among regions clearly exist.
- Finally the final cost estimates for each site and infrastructure excavation and each detector option was defined (detailed figures in documents)

GLACIER O(xxM€), LENA O(xxM€), MEMPHYS O(xxxM€)

LAGUNA site down-select

All seven pre-selected sites were considered for the feasibility of the underground infrastructure and for all three detector options

3x7 = 21 *a priori* cases

down-select

Outcome of deliberations to be included into next LAGUNA deliverables

- **Deliverable 2.8 : Final joint report on potential European sites**
- **Deliverable 1.2 : Final report on European underground research infrastructure and its science**

Until June 2011

- To be finalized by June 2011
  - 2.8 Final joint report on potential European sites
  - 3.2 Final report on safety
  - 3.3 Report on liquid procurement
  - 3.4 Report on socio-economic impact
  - 4.1 Deep science paper for general audience
  - 4.2 Scientific paper for the physics community
  - 1.2 Final report on European underground research infrastructure and its science

LAGUNA General meeting
(CERN, March 3-4, 2011)